8-2017

EVALUATING THE USE OF SELF-RELEVANT STIMULI IN ATTENTION BIAS MODIFICATION TRAINING AS A TREATMENT FOR ANXIETY: A NEAR-INFRARED SPECTROSCOPY STUDY

Jacob Scott Aday
Graduate Teaching Assistant - NMU Psychology Department, jaday@nmu.edu

EVALUATING THE USE OF SELF-RELEVANT STIMULI IN ATTENTION BIAS MODIFICATION TRAINING AS A TREATMENT FOR ANXIETY: A NEAR-INFRARED SPECTROSCOPY STUDY

By

Jacob S. Aday

THESIS

Submitted to
Northern Michigan University
In partial fulfillment of the requirements
For the degree of

MASTERS OF SCIENCE

Office of Graduate Education and Research

SIGNATURE APPROVAL FORM

EVALUATING THE USE OF SELF-RELEVANT STIMULI IN ATTENTION BIAS MODIFICATION TRAINING AS A TREATMENT FOR ANXIETY: A NEAR-INFRARED SPECTROSCOPY STUDY

This thesis by Jacob Scott Aday is recommended for approval by the student's Thesis Committee and Department Head in the Department of Psychology and by the Assistant Provost of Graduate Education and Research.

_____

Committee Chair: Dr. Joshua Carlson Date

_____

First Reader: Dr. Adam Prus Date

_____

Second Reader (if required): Dr. Antony Aumann Date

_____

Department Head: Dr. Adam Prus Date

_____

Dr. Lisa Eckert Date
Interim Director of Graduate Education and Research

ABSTRACT

EVALUATING THE USE OF SELF-RELEVANT STIMULI IN ATTENTION BIAS MODIFICATION TRAINING AS A TREATMENT FOR ANXIETY: A NEAR-INFRARED SPECTROSCOPY STUDY

By

Jacob S. Aday

Increased attentional bias to threat has been identified as a causal mechanism in the development of anxiety. As such, attention bias modification (ABM) was conceived as a treatment option where anxiety is alleviated through a computerized cognitive training regimen that reduces an individual's attentional bias to threat. However, few studies to date have examined how to tailor ABM treatments to unique individuals and how that may facilitate greater generalization of treatment effects in the real world. Additionally, the neural mechanisms underlying ABM are poorly understood. The participants in this study gave a list of the 10 things that caused them the most anxiety and those stimuli were incorporated into the ABM design in place of typically, experimenter-generated stimuli. A control group completed a self-relevant variant of the dot-probe task in place of ABM. Pre and post-testing, consisting of the dot-probe task while NIRS activity was recorded, did not reveal significant changes in behavior or brain activation. However, examination of the control group's data revealed that participants generally displayed an attention bias towards their self-relevant threats and that reaction time stabilized after an initial session, implying that a practice session may facilitate more reliable results with the dot-probe task. Interestingly, participants only showed an attention bias on trials involving the top half of the screen and attention bias scores garnered from top and bottom trials separately were highly correlated across sessions, suggesting that researchers may need to consider the spatial location of the target in order to draw more reliable results.

ACKNOWLEDGEMENTS

First off, I'd like to thank my family. Mom, Dad, Grandparents Jean and Gary, Grandparents Dorothy and Frank, Grandparents Lynn and Ken, Nathan, Trevor, Maddie, Caleb, and too many other family members to list have been incredibly supportive of the time and distance I've had to put between us to complete this project. Next, I'd like to thank my adviser, Dr. Josh Carlson, for his unwavering support and guidance throughout my time working with him. Without his patient and sage mentorship, I would certainly not be on the path that I am currently on. Thank you to Dr. Adam Prus for giving me a chance to get involved in research as an undergraduate as well as for his support in various other roles throughout my time at NMU. I'd like to thank these two aforementioned professors in particular for their commitment to making sure their students are prepared for graduate school and put in positions to succeed when they leave Northern. Thank you to Dr. Tony Aumann as well for unhesitantly agreeing to join my thesis committee. I'd also like to thank Floyd Steele and Bob Torrence for serving as excellent models of dedicated graduate students while I worked under them. Thank you to Grace Albert for all her help in the office; she has been a vital resource and friendly face throughout my time in the Psychology Department. Most pertinently, I'd like to thank all of the research assistants who assisted in the collection of this data: Jailin Kaiser, Erin Wylie, Lydia Morgan, Sarah Akans, Sydney Wardle, Grant Dorian, Travis Froberg, Katie Pershinke, Julia Mead, and Joe Novak. I cannot imagine how I could have completed this study without their help. Lastly, thank you to the Excellence in Education Research Program for funding this research.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF SYMBOLS AND ABBREVIATIONS

AB: Attention Bias

ABM: Attention Bias Modification

ABV: Attention Bias Variability

ACC: Anterior Cingulate Cortex

AR: Applied Relaxation

ATP: Adenosine Triphosphate

BDNF: Brain-derived Human Growth Factor

BNST: Bed Nucleus of the Stria Terminalis

BOLD: Blood-oxygen-level-dependent

CBT: Cognitive Behavioral Therapy

EEG: Electroencephalography

ERP: Event-related Potential

fMRI: Functional Magnetic Resonance Imaging

GAD: Generalized Anxiety Disorder

HbO: Oxygenated Hemoglobin

HbR: Deoxygenated Hemoglobin

lPFC: Lateral Prefrontal Cortex

MDD: Major Depressive Disorder

MRI: Magnetic Resonance Imaging

N2: ERP component with a negative peak at ~200 ms

ND: Nondirective Therapy

NIRS: Near-infrared Spectroscopy

OCD: Obsessive Compulsive Disorder

P1: ERP component with a positive peak at ~100 ms

P2/P200: ERP component with a positive peak at ~200 ms

P3: ERP component with a positive peak at ~300 ms

PD: Panic Disorder

PTSD: Posttraumatic Stress Disorder

rACC: Rostral Anterior Cingulate Cortex

RT: Reaction Time

SOA: Stimulus Onset Asynchrony

SSRI: Selective Serotonin Reuptake Inhibitor

STAI-S: Speilberger State-Trait Anxiety Inventory – State

STAI-T: Speilberger State-Trait Anxiety Inventory – Trait

vmPFC: Ventral Medial Prefrontal Cortex

INTRODUCTION

Anxiety disorders are currently among the most prevalent psychological disorders in the world. Current treatments, including pharmacological interventions, cognitive-behavioral therapy (CBT), and dietary and lifestyle changes, are limited by their potential negative side effects and at times limited efficacy. Additionally, one aspect of anxiety that current treatments do not directly target is the attentional deficits found in many anxious individuals. In particular, it seems that those high in anxiety also tend to display an attention bias towards threat, which simply put means that their attention is generally overly captured by threatening information. Attention biases can be quantified in the laboratory using the dot-probe task. In the task, participants are seated at a computer and each trial begins with a fixation cue in the center of the screen. After fixation, two stimuli are briefly presented with one on each side of the cue; one stimulus is generally threat-related while the other is emotionally neutral. After the stimuli disappear, a target dot appears in the location occupied by one of the two preceding stimuli. Those high in anxiety tend to respond faster to the target when it replaces threatening information, ostensibly because their attention was already directed or biased towards that side of the screen.

One treatment that has taken aim at the attention deficits found in anxiety is aptly named attention bias modification (ABM). ABM was conceptualized after research regarding attention biases and the dot-probe task began to emerge in the late twentieth century. ABM is a computerized cognitive training regimen designed to reduce attention biases toward threat and in-turn, anxious symptoms. The task is almost identical to the dot-probe task, however in the training, the target always appears behind the neutral stimulus and away from the threatening one. The rationale is that after some practice, participants will begin implicitly directing their attention towards the neutral stimulus in order to find the target quicker. The hope is that this

effect will generalize outside of training and participants will begin directing their attention towards threat less outside of the lab. Less time spent directing their attention towards threatening information is thought to lead to a reduction in anxious symptoms.

There is meta-analytic support for ABM as an anxiolytic intervention with over a decade of research. However, many questions remain regarding the neurobiological changes that accompany ABM as well as how the treatment may be tailored to unique individuals. To address this, we asked participants to provide a list of 10 things that cause them the most anxiety as well as a list of neutral words of equal length to incorporate into ABM training. Pre and post-testing consisted of participants completing a standard dot-probe task while NIRS activity was recorded from the PFC. Participants were split into a treatment and control group. The target always appeared behind the neutral word during the treatment group's training sessions and appeared non-contingently in the control group.

Anxiety

Anxiety disorders are currently among the most common diseases in the United States with 30% of Americans being diagnosed with one at some point in their lifetime (Hirschfeld, 2001). Additionally, Kessler (2005) reported that at any one point, roughly 18% of Americans suffer from an anxiety disorder. The economic burdens of anxiety disorders are substantial as well, costing an estimated $42.3 billion a year (Hoffman, 2008). There is a somewhat broad range of diseases grouped under anxiety disorders including generalized anxiety disorder (GAD), obsessive compulsive disorder (OCD), panic disorder (PD), social anxiety, and specific phobias (Hettema, Neale, Kendler, 2001; Kaufman & Charney, 2000). Anxiety disorders are highly comorbid with one another and other psychiatric conditions (Noyes & Hoehn-Saric, 1998). In particular, it has been reported that 50-60% of individuals with major depressive disorder (MDD) are also burdened with PD, social anxiety, PTSD, and/or GAD (Kaufman & Charney, 2000).

As a consequence of the broad range of ailments that fall under anxiety disorders, there is a very diverse assortment of treatments available. To date, the most common treatments include pharmacological interventions, psychotherapy, cognitive-behavioral therapy (CBT), and dietary or lifestyle changes (Bystritsky, et al., 2012; Bystritsky et al., 2013). With remission rates steadily hovering around 50% for CBT and pharmacological interventions, it is important to continue exploring alternative treatments that will yield lasting effects (Barlow, Gorman, Shear, & Woods, 2000; Ballenger, 2004; Cartwright-Hatton, Roberts, Chitsabesan, Fothergill, & Harrington, 2004).

Among the most common pharmacological treatments for anxiety disorders are selective-serotonin reuptake inhibitors (SSRIs), benzodiazepines, and antiepileptic agents (Bystritsky et al., 2013). However, these interventions can be less than ideal because of their potential side

effects and at times, limited efficacy. SSRIs have a disturbing number of potential adverse side effects including sexual dysfunction, sleepiness, weight gain, dry mouth, and insomnia (Cascade, 2009). Benzodiazepines have demonstrated their therapeutic efficacy, but there are an overwhelming number of potential side effects. The potential risks include, but are not limited to, high addiction rates, fatal overdose (especially if benzodiazepines are combined with alcohol), psychomotor impairment, memory impairment, depression and emotional blunting, adverse effects in pregnancy, and withdrawal symptoms (Longo, 2000). Because of the side effects of benzodiazepines, antiepileptic medications are beginning to be utilized more frequently; although they can produce similar adverse effects as benzodiazepines in higher doses (Bystritsky et al., 2013).

Several different psychotherapies have also been evaluated as treatments for anxiety disorders. Applied relaxation (AR) and cognitive behavioral therapies (CBT) appear to be superior to nondirective (ND) therapies for treating GAD (Borkovec, 1993). While psychotherapy treatments may not have the risks of pharmaceutical interventions, their efficacy has been questioned at times. Westen & Morrison (2001) found that while psychotherapy produced impressive short-term gains, most patients do not remain improved at clinically meaningful follow-up intervals. They also reported that screening procedures used in many studies raise questions about generalizability, particularly in light of a systematic relation across studies between exclusion rates and outcome (Westen & Morrison, 2001).

Alternative and complementary treatments are actually used more than conventional therapies by people with self-defined anxiety attacks and severe depression (Kessler et al., 2001). Alternative and complementary treatments, such as dietary or lifestyle changes, are similar in perceived effectiveness to conventional therapies (Kessler et al., 2001). However, the results may

not be generalizable because the majority of alternative and complementary treatments are conducted unsupervised (Kessler et al., 2001). All of these remedies have their tradeoffs between efficacy and negative side effects, illustrating the need for more effective treatments.

Given the prevalence of anxiety disorders, it is surprising that much is still unclear regarding the epidemiology of anxiety and what specific factors spur its development. The extent to which genetics contribute has been estimated to be from 14.3-31.6% according to multiple twin studies (Scherrer, et al., 2000; Hettema, Prescott, & Kendler, 2001). The researchers found no role for common environmental factors and no gender differences. However, it should be noted that many other studies have consistently found females to be at a greater risk of developing an anxiety disorder than males (Lewinsohn et al., 1998; Kinrys & Wygant, 2005; McLean, Asnaani, Litz, & Hofman, 2011; Sevar, Vythilingum, & Castle, 2015). There has been considerable disagreement about what happens to the risk of anxiety across individuals' lifespans. When controlling for other risk factors, Jorm (2000) found a consistent pattern of reduced susceptibility to anxiety as one ages. Although older adults are less likely to develop anxiety, they do report higher levels of disability related to the disease than younger adults (Brenes, et al., 2008).

Attentional Bias

Recent cognitive theories suggest information-processing biases towards threatening stimuli can lead to the development and maintenance of anxiety disorders (MacCleod, 2002). According to these theories, schemas largely influence how information is attended to, interpreted, and remembered (Bar-Heim, 2010). Schemas are thought to be biased towards threat in anxious individuals and thus their attention is inclined to attend to threatening information- leading to the development and maintenance of anxious symptoms. Support for this model comes from experimental data demonstrating that anxious individuals preferentially allocate attention (i.e. show an attention bias) towards threatening, as compared to positive or neutral, stimuli (Roy, et al., 2008; Bradley, Mogg, White, Groom, & de Bono, 1999).

Although there has been much support linking attentional bias and anxiety, the nature of this relationship differs across models. MacCleod, Mathews, and Tata (1986) were the first to demonstrate that anxious individuals consistently shifted attention towards threatening stimuli, while healthy subjects on the other hand tended to shift attention away from threat. The authors interpreted these results as supporting the existence of an anxiety-related encoding bias and suggest this cognitive mechanism leads to the development and maintenance of mood disorders. They posit that healthy individuals have a certain threshold that threatening stimuli must exceed before demanding processing resources. Since we encounter mildly threatening stimuli constantly in our daily lives, from oncoming vehicles that are potentially lethal to minor somatic sensations that may be signs of a greater malady, it would advantageous to exclude such stimuli from the cognitive system at an early stage of processing. Of course, when encountered with a clear threat- such as a skidding automobile or intense internal pain- they would appropriately avert attention towards the potential threat.

Anxious individuals on the other hand, do not seem to have such a threshold or if they do, it is much more sensitive to minor threats. This would explain the frequent negative affect displayed across anxiety disorders, arising presumably from excessive processing of mildly threatening and negative stimuli in their environment. MacCleod, Mathews, and Tata (1986) suggest that anxious individuals generally show a threat bias during the encoding stage of information processing and that subsequent processing biases may arise if the threatening information relates to areas of particular concern to the individual. Support for attentional biases arising during the encoding stage of information processing comes from a study conducted by Mogg, Mathews, and Weinmann (1987), who found that anxious individuals do not recall negative words any more accurately than positive words. This suggests a lack of attention bias towards threat during the retrieval stage of information processing. Altogether, the authors present a convincing argument that cognitive systems related to attention may differ radically between anxious and non-anxious subjects when processing threat-related information.

Given the accruing evidence supporting attentional biases towards threat-related information in anxiety and of memory biases for negative information in depression, Williams, Watts, MacCleod, and Mathews (1988) proposed a revised cognitive formulation of anxiety and depression emphasizing different patterns of cognitive bias. Anxiety is thought to be primarily characterized by biases in processes prior to awareness and in selective attention. Depression, on the other hand, is associated with a bias in post-attentive elaborative processes, which facilitate the recall of negative information- more akin to rumination, a common symptom of depression. Another pillar of their theory is that when under stress (state anxiety), those who have a tendency to direct attention towards threat (trait anxiety) are more susceptible to developing anxious symptoms. Finally, they suggest that there is a fundamental difference in the behaviors of high

and low trait anxious individuals when encountering threatening stimuli. High anxious individuals tend to orient attention towards threat, whereas low trait anxious individuals display the opposite effect, which is to be avoidant of threat. These differences are magnified in instances of high state anxiety. That is, high trait anxious individuals become hypervigilant of threat, while those with low trait anxiety become more avoidant of threat. Therefore, attentional biases are considered an interactive function of state and trait anxiety in this model.

This interactive model of attentional bias has received empirical support, although some aspects are still questioned. MacCleod and Mathews (1988) revealed no difference in attentional bias between high and low trait anxious individuals when tested several months prior to their final examinations, a time when state anxiety is presumably low. However, when tested a week prior to their final exams, when state anxiety levels are elevated, they found that high trait anxious students showed increased attentional biases towards threat, while low trait anxious students did not. This provides evidence for the first aspect of the interaction hypothesis (i.e. high trait anxious individuals are hypervigilant under stress), while there was a nonsignificant trend supporting the second aspect (i.e. low trait anxious individuals become more avoidant of threat stimuli under stress). These findings were corroborated by Mogg, Bradley, and Hallowell (1994) who found high trait anxious students become hypervigilant under exam-stress, while again there was a nonsignificant trend for low trait anxious individuals to become more avoidant.

Contrary to Williams, Watts, MacCleod, and Mathews assertion that anxious individuals attend to information that is threatening and non-anxious individuals avoid threat information, Mogg and Braldey's (1998) model suggest that all individuals attend to information they perceive as being threatening. The difference therefore lies in the appraisal of what stimuli pose a threat and those which do not. This theory is more in line with MacCleod, Mathew, and Tata's

original assertion in 1986 that attention biases arise in the encoding stage of information processing. Intuitively, this theory makes more evolutionary sense as well, given the importance of orienting attention towards perceived threats in the environment.

Several experimental paradigms have been utilized to study the relationship between attention bias and anxiety, namely the emotional Stroop, emotional spatial cueing, visual search, and most prominently dot-probe tasks (Bar-Heim, Lamey, Pergamin, Bakermans-Kranenburg, & van IJzendoorn, 2007). While it is thought that all of these paradigms reflect the workings of attentional processes, it also generally accepted that differences between tasks may reflect different aspects of attentional operations (Shalev & Algom, 2000). The emotional Stroop task is based on principles of cognitive interference; attention biases are represented by increased latencies in identifying the color of threat words relative to positive or neutral (Williams, Mathews, & MacCleod, 1996). The assumption is that information processing resources are biased towards attending to the threatening stimulus and that is manifested in increased reaction times. Another possible explanation is that increased latencies reflect greater cognitive effort required to divert attention away from negative stimuli. In the emotional spatial cueing task, targets appear in a region previously accompanied by a salient stimulus. Researchers compare reaction times from when the cue was congruently placed with the target and when it is incongruently placed away from the target to monitor attentional engagement with the stimulus. In the visual search task, participants are to indicate the presence or absence of some target among various numbers of distractors. Researchers can compare the slope of the reaction time as a function of display size to determine how different (particularly affective) stimuli capture attention when competing amongst neutral distractors (Trick & Enns, 1998).

The most common assessment of attention biases is the dot-probe task. The task begins with a fixation cue in the center of a blank screen. After a period of fixation, two stimuli are briefly presented (usually 100-500 ms)- one on each side of the screen. Once the stimuli are removed, a target appears on either the left or right side of the screen. Typically when assessing attention biases towards threat, one of the stimuli is neutrally valenced while the other is threat-related. Trials containing the target behind the neutral stimulus are considered to be "incongruent" trials, while targets replacing the threat-related stimulus are considered "congruent" trials. Faster reaction times when the target replaces the threat-related stimulus are thought to represent facilitated orienting of spatial attention towards threat. Meanwhile, delayed reaction times when the target replaces the neutral stimulus are thought to represent delayed disengagement of attention from threat (Koster, Crombez, Verschuere, & De Houwer, 2004; Carlson & Reinke, 2008; Carlson & Reinke, 2010; Carlson, Reinke, LaMontagne, & Habib, 2011; Carlson & Mujica-Parodi, 2014). Therefore, threat-related stimuli are thought to capture attention quicker (facilitated orienting) and for longer (delayed disengagement) than neutral stimuli in many anxious individuals.

There is substantial empirical evidence supporting the notion that individuals with anxiety and other mood disorders tend to take longer to respond during incongruent compared to congruent trials (MacCleod, Mathews, & Tata, 1986; Mogg, Mathews, & Eysenck, 1992; Mogg, Bradley, & Williams, 1995). That is, their attention seems to fixate on the threatening stimulus longer than healthy participants. This is indicative of their real-life experiences characterized by an excessive allocation of attention towards threatening and negative events and stimuli.

Although simple and effective, the dot-probe task is not without its questions, limitations, or controversies. First, evidence accrued from the task can be somewhat ambiguous as the results

can be interpreted as difficulty to disengage from threat or facilitated orienting towards threat. However, this concern was addressed in a study by Koster, Crombez, Verschuere, and De Houwer (2004) who found the dot-probe effects to be due at least partially to delayed disengagement rather than facilitated orienting when comparing with baseline neutral trials. Other concerns regard internal consistency and test-retest reliability of the task (Schmukle, 2005). However, the dot-probe task remains the most utilized method of assessing attention biases and has consistently produced orienting and disengagement effects in our lab (Carlson & Reinke, 2008; Carlson & Mujica-Parodi, 2014).

Attention Bias Modification

Attention bias modification (ABM) is a cognitive training treatment for anxiety that utilizes computer-based training protocols to implicitly modify biased attention patterns in anxious subjects. ABM developed from literature indicating that attentional biases towards threat play a causal role in the development of anxiety (MacCleod, Mathews, & Tata, 2002). Most ABM treatments are based off a variant of the dot-probe task (Bar-Heim, 2010). In the training, two stimuli are briefly presented for around 500 ms- one on each side of the screen; one is a threat-related stimulus and the other is neutral or non-emotional. After a period of fixation, a dot will appear on one side of the screen and the participant must indicate its location using a response box. During a standard dot-probe task, the target appears an equal number of times behind the threat-related and non-emotional stimulus. However, during ABM, the target *always* appears behind the non-emotional stimulus. The rationale behind the training is that after some practice, participants will begin implicitly orienting their attention away from the threat-related stimulus and towards the neutral or non-emotional stimulus in order to successfully find the target. The hope is that after a period of training, participants will begin attenuating their bias towards threat in the real-world. This should in turn lead to a reduction in anxiety as their attention is bombarded less with threatening stimuli.

After more than a decade of research, there are now a number of recent reviews (Bar-Heim, 2010; Kuckertz & Amir, 2015; Beard, 2011; Browning, Holmes, & Harmer, 2010; Hertel & Mathews, 2011; MacCleod & Mathews; 2012) and meta-analyses (Hakamata et al., 2010; Mogoase, David, & Koster, 2014; Beard, Sawyer, & Hofman, 2011; Hallion & Ruscio, 2011) indicating that ABM is successful in reducing attentional biases towards threat and anxious symptoms. The efficacy of ABM has been shown to be comparable to the more costly SSRI and

CBT treatment options in randomized control trials with anxious patients (Hakamata et al., 2010). Additionally, ABM has the added advantage of being incredibly accessible as it can be administered at-home (See, MacCleod, & Britle, 2009), in the lab (Britton et al., 2015), over a cellphone (Aday & Carlson, in-preparation), or over the internet (MacCleod, Soong, Rutherford, & Campbell, 2007). ABM's anxiolytic effects also appear to be maintained long-term as evidenced by a study conducted by Schmidt, Anthony, Buckner, and Timpano (2009). The researchers found that ABM resulted in reduced scores on a social anxiety measure compared to a control group four months after the training had ceased. Altogether, ABM appears to be a promising treatment option that is noninvasive and practical with lasting effects.

Neural Correlates of Attention Bias Modification

It is important to understand the neural mechanisms underlying effective ABM treatment in order to more objectively measure training-related outcomes as well as further elucidate how alterations in brain function and structure contribute to psychopathology. There is a growing literature linking changes in attentional bias to changes in brain regions involved in attentional control [i.e. the lateral prefrontal cortex (lPFC) and anterior cingulate cortex (ACC)] and emotional processing (i.e. amygdala; Wiers & Wiers, 2016). However, considerable disagreement remains regarding exact localization of these neurobiological changes as well as degree. Next, the neural mechanisms commonly implicated in affective attention in general will be briefly introduced. Then, we will review the existing literature on ABM and changes in brain function and structure. The neuroimaging techniques used to study ABM treatments will also be explained.

Affective attention is thought to be mediated largely by a broad network that includes the amygdala, ACC, and sensory cortex (Carlson, Reinke, & Habib, 2009). The amygdala is primarily thought to appraise a stimulus for its saliency and threat potential (Adolphs et al., 1999; Adolphs, 2004; Adolphs et al., 2005). There is also research supporting its involvement in coding the spatial location of potential threats (Peck, Lau, & Salzman, 2013). Axons from the amygdala project to spatially-specific locations in the visual cortex in order to facilitate visual processing at the location of potential threat (Adolphs, 2004; Vuilleumier, Richardson, Armony, Driver, & Dolan, 2004; Carlson, Reinke, LaMontagne, & Habib, 2011). The ACC's role in affective attention is thought to be resolving conflict between stimuli competing for attention (Botvinick, Nystrom, Fissell, Carter, & Cohen, 1999) as well as regulating the duration of attentional capture by threatening stimuli (Price et al., 2014).

EEG & ABM

Electroencephalography (EEG) is a noninvasive method of recording electrical activity produced by the brain using electrodes along the scalp. It is classically well-regarded for its temporal resolution (millisecond range) but is considered to have poor spatial resolution as the source of electrical activity cannot be localized with certainty (Burle et al., 2015). EEG data is represented as a series of positive and negative amplitudes over time known as oscillations. These oscillations are considered to be the sum of activity of large neuronal masses after neurons have fired. In order to link changes in EEG data and behavior, an averaging procedure centered around a particular stimulus event is commonly used on the data; the measure yielded from this type of analysis is known as an event-related potential (ERP). ERP components are named for their valence and latency or order. For example, an increase in activity 200 ms after stimulus onset could be labelled as P200- the "p" representing positive and "200" representing the 200 ms latency. The same component could be labelled as P2 if it is was the second positive inflection following stimulus onset (i.e. order-based labelling). ABM studies utilizing EEG commonly see changes in activity before stimuli reach awareness (~100-200ms), suggesting that ABM influences changes early on in the stages of information processing and likely during the orienting of attention. Changes in later stages of processing have also been reported (Eldar & Bar-Heim, 2009).

The first study to examine the neural correlates of ABM was conducted on 30 anxious and 30 healthy non-anxious controls by Eldar and Bar-Heim (2009). The researchers were examining the effects of a single session of ABM training (480 trials) while having their brain activity monitored with EEG. The two groups were evenly divided into a treatment group whose attention was always directed away from threat-related stimuli and a control group whose

attention was directed evenly towards threatening and non-threatening information. They found that only anxious individuals in the treatment group had their attention biases attenuated- suggesting that a preexisting bias is necessary for ABM to be effective. N2 amplitudes, which are involved in attentional control processes, were enhanced in anxious individuals, whereas the control group displayed decreased N2 amplitudes. They also found that anxious individuals in the treatment group showed decreased P3 amplitudes after training- more resembling the P3 amplitudes of non-anxious individuals. Importantly, anxious individuals in the control group showed no such attenuation of P3 amplitudes. Taken together, the authors suggest that ABM facilitated normative neuronal habituation processes among anxious individuals by decreasing their overall processing efforts and increasing attentional control.

Another EEG study was used to assess the effects of ABM, but this time using only a non-clinical sample (O'Toole & Dennis, 2012). The participants were split into a treatment condition where their attention was always directed away from threat and another group whose attention was always directed towards threatening stimuli. Again, the researchers found that training changed attentional bias for threatening stimuli, but only in those demonstrating a pre-training attentional bias- replicating the findings of Eldar and Bar-Heim (2010). They also found that ABM moderated early spatial attention in the treatment group as demonstrated by decreased P1 amplitudes. This effect was contrary to that previously found by Eldar and Bar-Heim (2010), possibly due to differences in experimental design or ABM differentially affecting anxious and non-anxious individuals.

fMRI & ABM

Functional magnetic resonance imaging (fMRI) is a noninvasive method of measuring brain activity that relies on changes in hemodynamic signaling rather than changes in electrical

activity like EEG (Logothetis, Pauls, Augath, Trinath, & Oeltermann, 2001). When a neuron fires, it requires energy in the form of adenosine triphosphate (ATP), which is produced by oxidizing glucose. Oxygen is delivered by hemoglobin via blood vessels and this forms the basis of the blood-oxygen-level-dependent (BOLD) signal recorded by fMRI. Given the relatively long chain of events leading up to a BOLD signal, it should be unsurprising that fMRI has poor temporal resolution (changes in BOLD signal are typically recorded 0.5-5 seconds following neural activation). The tradeoff is that is capable of excellent spatial resolution, allowing for localization of activity to specific brain regions. To date, fMRI has been the most common method of measuring the neural effects of ABM (Wiers & Wiers, 2016).

The first fMRI study to examine the effects of ABM was conducted on 29 healthy subjects who were split into a treatment condition ("avoid threat") where their attention was always directed away from threat and another condition ("attend threat") in which their attention was always directed towards threat (Browning, Holmes, Murphy, Goodwin, & Harmer, 2010). The researchers found that the training induced an attentional bias towards threat in the attend threat group as hypothesized, while this effect was not found in the treatment group. They also discovered that activity in the lPFC increased across all groups and experimental conditions when the direction of the participant's spatial attention was directed opposite that of their training. The authors suggest that is due to an increased need for attentional control after learning to direct their attention in the opposite direction during training. A small region of the rostral anterior cingulate cortex (rACC) was found to exhibit the same pattern of activity as the lPFC, suggesting that the lPFC may be one node in a larger control circuit that incorporates the rACC. This network hypothesis was further supported by a matching pattern of activity in the bilateral

striatum. The non-differential neural effects found between groups creates some ambiguity regarding the neural mechanisms by which ABM exerts anxiolytic effects.

Multiple fMRI studies of ABM have reported alterations in fronto-amygdalar activation following training. Britton et al. (2015) found that greater left amygdala activation to congruent trials at baseline was associated with greater symptom reduction across both training groups. Additionally, after accounting for group differences in baseline amygdala activation, assignment to one or the other training conditions further predicted changes in symptoms, with greater symptom reduction in the active ABM group. These findings corroborated previous work done by Taylor et al. (2013) who found attenuated activation of the bilateral amygdala following a single session of ABM in individuals with social anxiety. These individuals also demonstrated greater activation in several regions of the PFC after training. Importantly, those with greater enhancement of ventral medial prefrontal cortex (vmPFC) activation following training showed more diminished attentional bias towards threat and decreased anxiety to an experimental stressor. Collectively, these findings suggest that ABM fosters deployment of top-down neural processes aimed to regulate anxiety and the neurobiological locus of these processes seems to be heavily centered around fronto-amygdalar structures.

MRI & ABM

Magnetic resonance imaging (MRI) is one of the most commonly used techniques to noninvasively examine brain structure. MRI scanners use strong magnetic fields, radio waves, and field gradients to form images of the brain and body. In brief, MRI scanners use strong magnets to align hydrogen molecules that are largely found in water and fat in the human body. By varying the pulse sequence, contrasts can be created between tissues based on the movement of hydrogen molecules. Since its beginnings in the 1970s, MRI has become one of the most

versatile and useful imaging techniques used in medicine and research. To date, there has been only a single preliminary MRI study on the structural changes that accompany ABM training (Aday & Carlson, in-preparation) and few examining attention bias and brain structure (Carlson et al., 2012; Carlson, Cha, Harmon-Jones, Mujica-Parodi, & Hajcak, 2014).

Carlson, Cha, Harmon-Jones, Mujica-Parodi, and Hajcak, (2014) demonstrated that heightened attentional biases toward threat correlate with greater structural integrity of the amygdalo-prefrontal tract (uncinate fasciculus). Genetic variations associated with brain-derived human growth factor (BDNF) appear to influence the microstructure of this pathway, which in turn, affects attention bias toward threat. This led the authors to suggest that attentional processes are heavily influenced by threat signals via the uncinate fasciculus in individuals with high attention biases. These findings complemented earlier research demonstrating that greater gray matter volume in the ACC is correlated with attention bias to threat (Carlson et al., 2012). Overall, the two studies suggest a strong link between attention bias and structural volumes in frontal regions and the amygdala.

Further support for the involvement of frontal regions and the amygdala in attention bias comes from an ABM study looking at structural volumes pre and post-ABM training. Aday and Carlson (in-preparation) recruited participants to undergo 6 weeks of ABM training utilizing a cellphone app. They found that training resulted in decreased gray matter volume in the extended amygdala region, likely in the bed nucleus of the stria terminalis (BNST), as well as the ACC (**Figure 1**). These changes in gray matter volume were highly correlated with changes in attention bias, such that those with the greatest reductions in gray matter also had the greatest reductions in attention bias. These results provide converging evidence for attention bias being associated with gray matter volume in these regions given the positive correlations previously

reported between attention bias and gray matter volume in the ACC. Although the data is preliminary with only 6 participants completing ABM and no control group, the findings are intriguing given how they complement previous studies looking at attention bias and structural volumes in the prefrontal cortex and amygdala. A hypothesized model of the neural mechanisms underlying effective ABM treatment is illustrated in **Figure 2**.

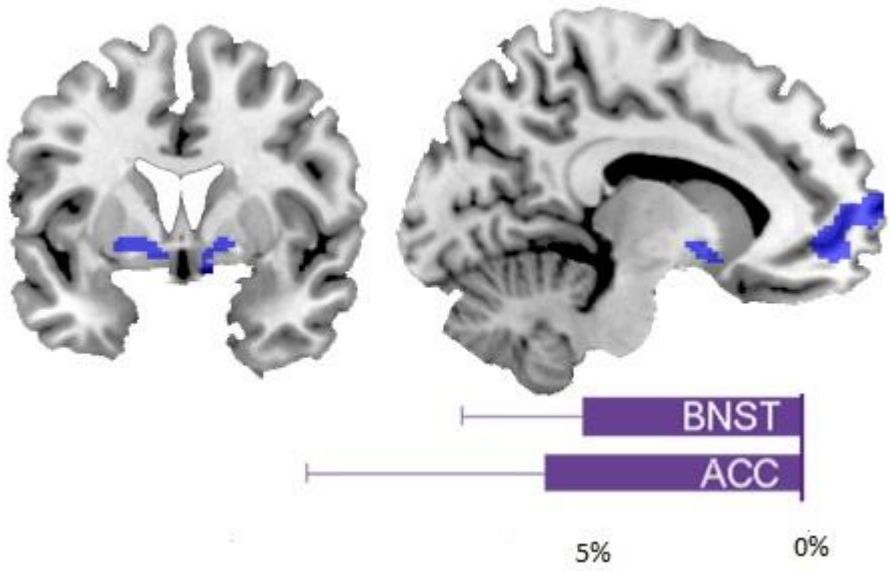


Figure 1. Aday & Carlson ABM MRI Results. After 6 weeks of ABM training, Aday & Carlson (in-preparation) found that gray matter volume in the ACC and BNST reduced by 5-6%

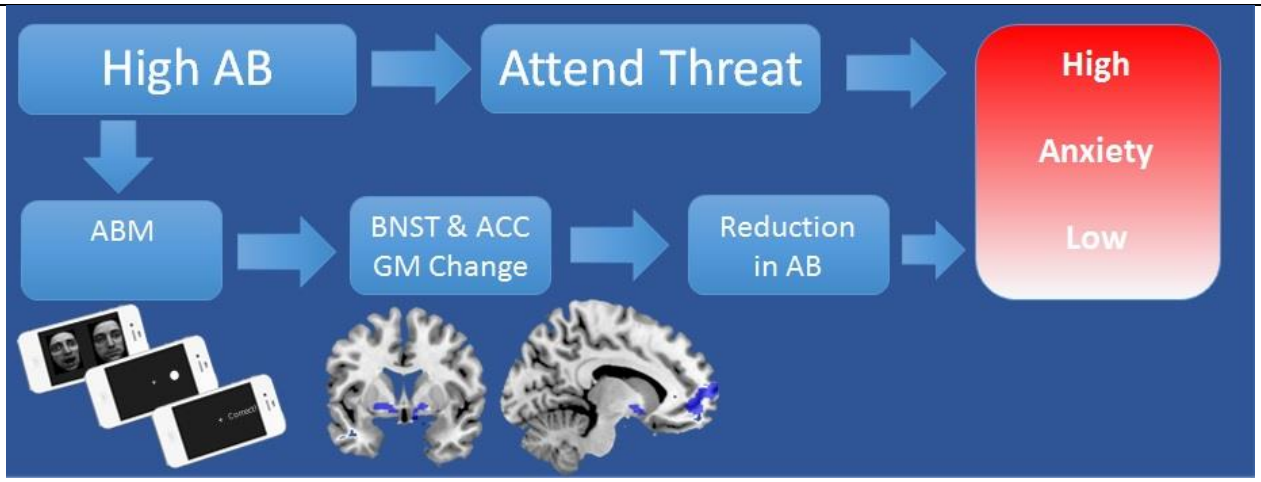


Figure 2. ABM Model. Pictured is a model illustrating how high attention bias (AB) results in high anxiety and how ABM reduces anxiety through a reduction in gray matter volume in the BNST and the ACC (Aday & Carlson, in-preparation).

Near-infrared Spectroscopy (NIRS)

Near-infrared spectroscopy (NIRS) is a noninvasive method of measuring brain activity in the cerebral cortex utilizing near-infrared light. It is an attractive option for monitoring brain function as it is much more cost-friendly and has greater mobility than fMRI, while it also has the ability to localize activity to a given region of the cortex unlike EEG. The main limitation with NIRS is that it is only able to monitor activity within the first centimeter of the cortex (Boas & Franceschini, 2009).

NIRS is based on the premise that oxygenated (HbO) and deoxygenated hemoglobin (HbR) serve as indirect measures of neural activity. As described earlier, neurons need ATP to fire, which is provided by oxidizing glucose. Oxygen is provided by recruiting blood vessels which store hemoglobin. HbO and HbR are known for being the strongest absorbers of visible and near-infrared light, meaning that changes in hemoglobin concentrations can be monitored based on the amount of light absorption. NIRS uses an array of sources to emit near-infrared light and detectors to monitor how much light is absorbed. Of course, some of the light is absorbed by surrounding tissue and some of the light exits the head without detection, but HbO and HbR are the believed to be the largest absorbers of near-infrared light (Orbig et al., 2000).

To date, no studies have been published examining the effects of ABM treatment using NIRS. However, participants performing the same task using NIRS and fMRI have demonstrated that the two measures are highly correlated with one another (Mehagnoul-Schipper et al., 2002). NIRS and fMRI measures are both based on changes in blood flow in the brain so we should expect to see similar results as previous studies examining fMRI and ABM. Since the PFC has been implicated in nearly all neuroimaging studies of ABM, it would seem to be an ideal location to place the NIRS probe. The PFC is also an ideal location for using NIRS because hair

can block some of the light being emitted by the sources and shield detectors when examining other lobes of the cortex. Using NIRS, our lab has demonstrated decreases in mPFC activity during the dot-probe task following ABM training (Aday & Carlson, in-preparation; **Figure 3**), although this data has not been published. Since no other studies to date have examined the effect of ABM on NIRS activity, our a priori hypotheses regarding NIRS activity will reflect this preliminary data and fMRI studies of ABM.

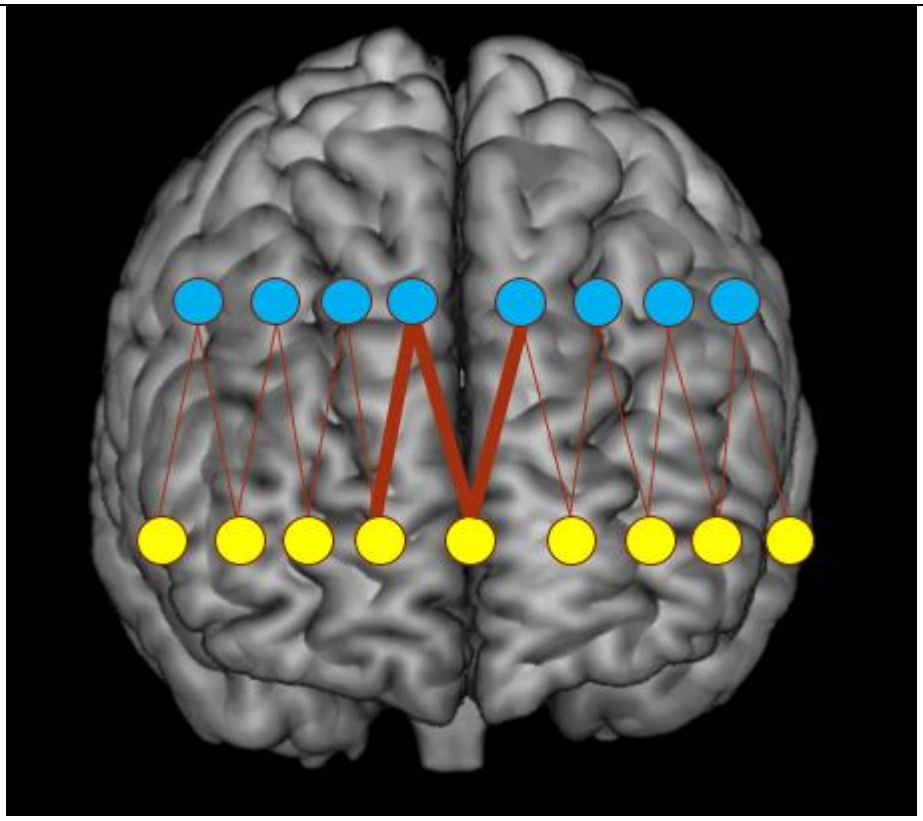


Figure 3. Aday & Carlson ABM NIRS Results. Aday & Carlson (in-preparation) found that ABM training resulted in a decrease in HbR over mPFC optode connections (bolded) during the dot-probe task.

Individual Differences

To date, there has been somewhat mixed evidence regarding individual differences that are pertinent to treatment outcomes. Multiple studies report that an individual's pre-training attention bias is a reliable predictor of treatment outcomes (Aday & Carlson, in-preparation; Amir, Taylor, Donohue, 2011; Heerin, Philippot, & Koster, 2015; Mogoase, David, & Koster, 2014; Kuckertz et al., 2014). This makes sense given the reduction in anxiety is thought to be facilitated by a reduction in attention bias. Individuals without a pre-training attention bias would ostensibly have little to gain from the treatment if their anxiety is due to reasons other than an attentional bias. One study, however, has reported that baseline attention bias scores are not related to symptom reductions (Britton, Suway, Clementi, Fox, Pine, & Bar-Heim, 2015). This may be due to differences in experimental design though since in general, pre-training attention biases seem to be a reliable predictor of treatment outcomes.

Individual differences in stimuli that induce anxiety may also relate to treatment outcomes. The stimuli presented during ABM training are typically experimenter-generated words or faces. No studies to date have examined how incorporating self-relevant stimuli into the task affects treatment outcomes. It would seem that since ABM's anxiolytic effects stem from an attenuation of attention on stimuli that cause one anxiety in their daily lives, training individuals to direct attention away those same stimuli, rather than general threat-related stimuli, would facilitate treatment effects. As such, this study was designed to examine how ABM treatments can be tailored to unique individual needs in the hopes of refining treatment protocols as well as provide further information regarding how ABM changes brain function.

THESIS STATEMENT

This experiment was designed to assess the efficacy of incorporating self-relevant stimuli into the ABM protocol as well as further elucidate the neural mechanisms of effective ABM. There is currently a gap in the literature regarding how ABM treatments can be tailored to unique individuals and how that may facilitate treatment effects. There is also somewhat inconsistent data on the neural workings of ABM. Many studies of ABM fail to include a control group, which will also be addressed in this experiment. I hypothesize that:

1) ABM will result in reduced attentional biases towards threatening stimuli in the treatment group as compared to baseline and the control group.
2) The reduction in attentional bias will facilitate a reduction in anxious symptoms in the treatment group compared to baseline and the control group.
3) ABM will result in overall increased activity in the lPFC after training in the treatment group but not in the control group.
4) ABM will result in overall decreased activity in the mPFC after training in the treatment group but not in the control group.
5) Changes in PFC activity in response to training will be correlated with reductions in attention bias and anxious symptoms.

METHODS

Participants

59 participants (Female = 44, Mean Age = 19.86; **Table 1**) from Northern Michigan University and the surrounding Marquette, Michigan area were recruited to participate in the experiment. Participants were recruited by hanging flyers around the university and town and compensated $24 for their time commitment to the project. The sample size was determined based off a sample size estimate performed using G*Power with an effect size of 0.70, power level of 0.85, and an alpha level 0.05. Bar-Heim (2010) previously reported an effect size of 0.61 in his review, but we expected to see a slightly higher effect size since the training was tailored to each individual. All participants provided informed consent before beginning the experiment and were told that they were allowed to drop out of the study at any time. The study was approved by the Northern Michigan University Institutional Review Board (Project # HS16-723).

Group	Age	Gender	Pre STAI-T	Pre STAI-S	Pre AB
Treatment	19.61	F = 21, M = 9	46.81	45.50	6.86
Control	20.22	F = 23, M = 6	43.87	43.70	12.37

Table 1. Participant Demographics: Table 1 notes pre-training demographic information including: age, gender, STAI-T, STAI-S, and attention bias.

Stimuli

Testing Sessions

The stimuli presented during testing sessions in the dot-probe task consisted of 10 unique facial identities (female = 5) expressing fearful and neutral facial expressions. The faces were acquired from a standard facial database (Gur et al., 2002; Lundqvist, Flykt, & Ohmnan, 1998).

The stimuli were presented for 100 ms on a black background before being replaced with a white dot (**Figure 4**).

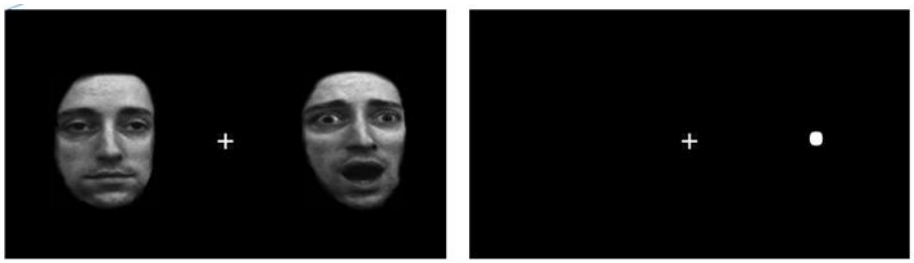


Figure 4: Dot-probe Task. Pictured is a trial from the dot-probe task. Faces were presented for 100 ms and then followed by a target dot.

Training Sessions

The stimuli presented during training sessions consisted of 10 words the participant previously reported as causing them anxiety and 10 neutral words of equal length acquired from the Affective Norms for English Words List (Bradley & Lang, 1999). Words in this list are ranked from 0-10 on emotional valence (negative to positive). Words rated between 4-6 (within 1 standard deviation of a "neutral" valence) were compiled into a list and participants selected words that they considered to be emotionally neutral to them. They were instructed to select a corresponding neutral word of equal length for each anxiety-related word. The first 10 participants had their neutral words chosen at random before we made the decision to have the participants select their own neutral words in order to tailor the task further. Words were presented in white text on a black background for 500 ms followed by a white target dot (**Figure 5**).

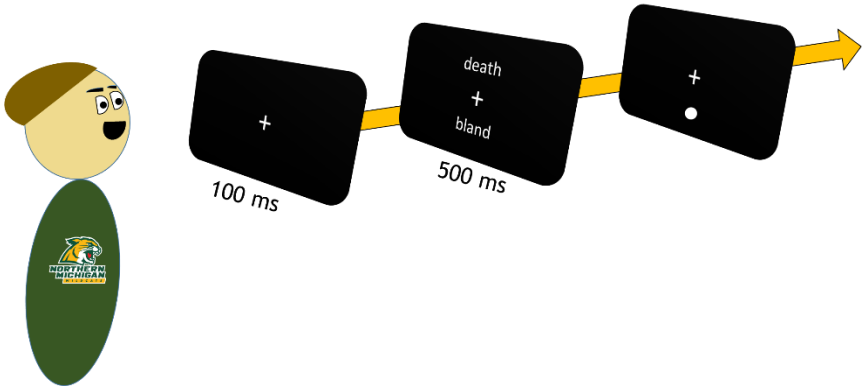


Figure 5: Self-relevant ABM Training. Pictured is a trial from the self-relevant ABM training. Words were presented for 500 ms and then followed by a target dot. The target always followed the neutral word in the treatment group and appeared non-contingently in the control group.

Tasks & Equipment

Testing Sessions

The dot-probe task presented during testing sessions was programmed using E-Prime2 software and displayed on a 60Hz 16" PC computer monitor. Responses were made by pressing the "1" or "2" buttons on a Chronos Response Box (**Figure 6**). The experiment was divided into four blocks. Each trial of the experiment began with a white plus sign (+) centered on a black screen for 1,000 ms. Next, two faces were briefly flashed- one on each side of the plus sign. One was a fearful facial expression and the other a neutral facial expression. On some trials, two neutral faces were presented to serve as a baseline. After a period of fixation, the faces disappeared and were replaced with a small white dot on one side of the screen. The participants' task was to indicate which side of the screen the dot appeared on by pressing "1" for left-sided targets and "2" for right-sided targets. Dots were presented an even number of times behind the neutral and fearful facial expressions. An attentional bias is demonstrated by quicker reaction times when the dot appears behind the fearful faces- implying that the participant's attention was already directed there. This effect can also be demonstrated by longer reaction times when the

dot appears behind the neutral face- implying that the participant's spatial was captured longer by the fearful face. NIRS activity was recorded across the PFC during both pre and post-training testing sessions.

Figure 6: Chronos Response Box. Pictured is the Chronos Response Box participants used to identify the location of target dots. They pressed the first leftmost button with their right index finger to indicate target dots on the left and the second button with their right middle finger to indicate target dots on the right. The first four buttons were used to record responses to the questionnaires.

Following the dot-probe task, participants were asked to fill out both the State (STAI-S) and Trait (STAI-T) versions of the Speilberger State-Trait Anxiety Inventory (Spielberger, Gorsuch, & Lushene, 1970) to assess individual differences in both state and trait anxiety levels, respectively. Participants indicated the degree to which they agreed with various statements (1-4) using the Chronos Response Box. State anxiety was recorded before trait anxiety.

Training Sessions

The ABM task used during training sessions was designed with E-Prime2 and run on a 60Hz 16" computer monitor. Participants made their responses using a Chronos Response box.

The training sessions were divided into four blocks with a short break in between blocks to reduce fatigue. Each trial of the training sessions began with a white plus sign (+) centered on a black screen. Then, two words were briefly presented- one on the top and one on the bottom half of the screen. One word was a stimulus they previously reported as causing them anxiety and one was a neutral word of equal length. After a short period of presentation, the words disappeared and were replaced with a small dot on one half of the screen. The dot always appeared on the same side of the screen as the neutral word in the treatment group and an equal number of times behind threat-related and neutral words in the control group. The participants' task was to locate this dot by pressing "1" for top-sided targets and "2" for bottom-sided targets.

Neuroimaging Equipment

Brain activity was monitored during testing sessions using a TechEN CW6 NIRS system. The CW6 emits 690nm and 830nm wavelengths of light, which are optimal for tracking HbO and HbR. Light was emitted and detected using an optode array that spans the lateral to medial anterior PFC. The array was made using plastic and foam padding provided by TechEN and consists of 8 sources and 9 detectors. Detectors and sources were separated by 3 cm, which is the ideal distance for measuring the cortical surface (Boas & Franceschini, 2009). The study utilized the 10 – 20 EEG system to standardize probe placement across participants. This was done by measuring the distance from the nasion (bridge of the nose) to the inion (bump on back of the skull). The central detector (detector 5) was placed 10% of this distance above the nasion, which is the Fpz coordinate, so that it spanned the anterior PFC (**Figure 7**). The probe was secured with a Velcro fasten, followed by a headband, and an Ace bandage to stop light from leaving or entering the region of interest. A TechEN 8 BNC connector was used to send stimulus markers

from E-Prime2 to the CW6 program in order to identify the timing and type of trial. A Patriot 3D digitizer was used to synchronize probe placement with 10-20 landmarks on the head.

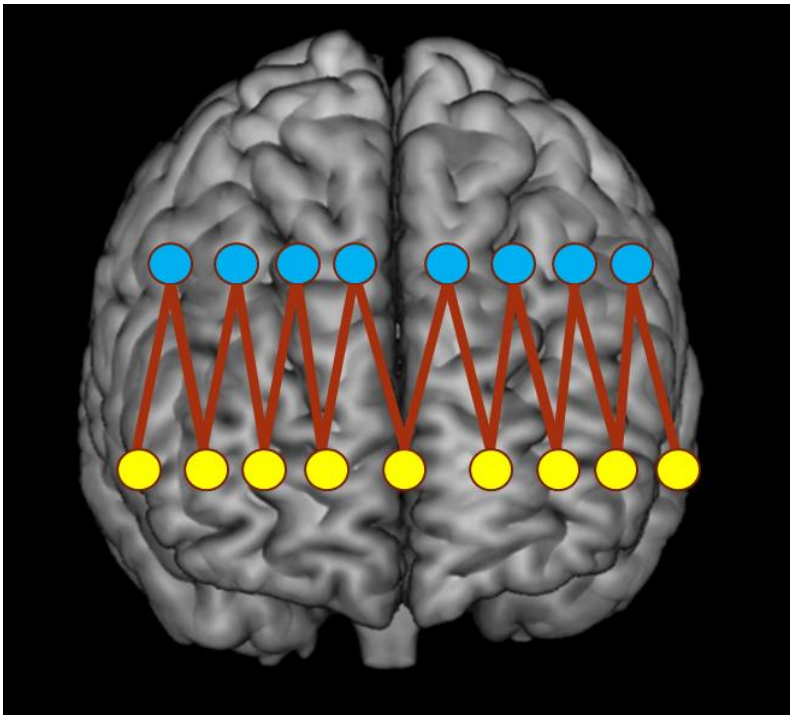


Figure 7: NIRS Placement Over the PFC. The central detector was placed over coordinate Fpz so that the NIRS probe spanned the anterior PFC.

Neuroimaging Preprocessing

NIRS data was analyzed using HOMER2 software in MATLAB. Light intensity was converted to optical density using the following parameters: PCA: 0.9, tMotion: 0.5, tMask: 1.0, STDEVthresh: 50.0, AMPthresh: 5.0, and lowpass filter: 0.5. Data collected 2-5 seconds post-stimulus onset was averaged together for each trial type and channel during testing sessions 1 and 2.

Procedure

When participants arrived for their first session, they were immediately prompted to fill out the informed consent sheet and asked if they have any questions regarding the study. Then, basic demographic information was collected (i.e. email, phone, gender, age, and handedness) and entered into a Microsoft Excel spreadsheet. The participants were randomly assigned to either the treatment or control group during this time. Next, they scheduled what days they were available to participate in the next two weeks using a Google calendar. A team of 1 graduate research assistant and 9 undergraduate research assistants who have completed CITI training for working with human subjects aided in running participants during their testing and training sessions.

After collecting informed consent and basic demographic information, the participants were asked to give a list of the 10 things that cause them the most anxiety. Each answer was limited to one 3-11 letter word because of logistical limitations with the ABM design. That is, participants may not have time to read words longer than that in 500 ms, plus an affective database for phrases would be needed to match a neutral phrase with their anxiety-provoking phrase. If they had trouble coming up with a list of 10 things that cause them anxiety, they were prompted to think of things they find threatening or worrying. The participants' lists were programmed into the ABM design using E-Prime2 before their first training session.

After providing their list of 10 things that cause them anxiety, participants began their first testing session. The NIRS device was secured to the participants' foreheads using 10 – 20 landmarks and they were situated 59 cm from the computer screen. The research assistant then read aloud the instructions for the participant. The participant's task was to locate a dot that followed the presentation of two faces. There was a 7-second gap in between trials in order for cortical hemoglobin activity to return to baseline. The participants were instructed to try to keep

their mind free from distractions during that time and to focus on the task. Once the dot-probe task was over, the research assistant turned off recording of the NIRS device and prompted the participant to begin the STAI to assess state and trait anxiety.

After their first testing session was over, they were immediately guided down to the CABIN lab to begin their first training session. This was done immediately after their testing session in order to reduce the number of times a participant must travel to the facilities. The participant was brought to a testing room and told to wait until further instruction while the research assistant prepared the experiment. The researcher then incorporated the 10 things the participant identified as causing them anxiety and their 10 neutral words into the E-Prime2 software. Once the experiment was programmed, the research assistant entered the testing room to read aloud the instructions. The participants were told to identify the location of a dot, which always appeared on the same side of the screen as the neutral word in the treatment group and non-contingently in the control group. The expectation was that participants in the treatment group would begin implicitly orienting their attention away from threat during the task and this effect would generalize outside of the lab. An attenuation of attentional bias towards threatening stimuli in their daily lives should result in anxiolytic effects as they are bombarded less with negative and threatening information. Since the dot location is not contingent upon the emotional valence of the preceding words in the control group, we did not expect to see an attenuation of attentional bias towards threat among those participants.

After the training session was over, the participants were reminded of when their next training session was and then they were free to leave. Their final training session was immediately followed by their final testing session; again, in order to reduce the number of times participants must travel to the facilities. Once they completed their final testing session, they

were debriefed on the nature of the experiment and told to stop by my office for their check of $24. Funds for the project were secured from the Excellence in Education Research Program at NMU.

Analytic Plan

Analytic plan for Hypothesis 1: **ABM will result in reduced attentional biases towards threatening stimuli in the treatment group as compared to baseline and the control group.** A 2 x 2 analysis of variance was conducted to conclude if ABM training reduces attentional biases compared to baseline and the control group. Attentional biases were calculated by taking the mean reaction time on incongruent trials minus the mean reaction time on congruent trials. Trials in which participants responded faster than 150 ms or slower than 750 ms were excluded as outliers.

Analytic plan for Hypothesis 2: **The reduction in attentional bias will facilitate a reduction in anxious symptoms in the treatment group compared to baseline and the control group.** A 2 x 2 analysis of variance was used to conclude if ABM training reduces self-reported anxiety as measured by the STAI-S and STAI-T compared to baseline and the control group. Pre and post-training anxiety scores were correlated with changes in attentional bias using a Pearson correlation.

Analytic plan for Hypothesis 3: **ABM will result in overall increased activity in the lPFC after training in the treatment group, but not in the control group.** A mixed methods analysis of variance was used to assess whether ABM results in increased activity in the lPFC compared to baseline and the control group.

Analytic plan for Hypothesis 4: **ABM will result in overall decreased activity in the mPFC after training in the treatment group, but not in the control group.** A mixed methods analysis of variance was used to assess whether ABM results in decreased activity in the mPFC compared to baseline and the control group.

Analytic plan for Hypothesis 5: **Changes in PFC activity in response to training will be correlated with reductions in attention bias and anxious symptoms.** Pearson correlations were run in order to determine the relationship between changes in PFC activity, attention bias, and anxious symptoms.

RESULTS

Hypothesis 1: ABM will result in reduced attentional biases towards threatening stimuli in the treatment group as compared to baseline and the control group. Attention bias (AB) scores garnered from the pre and post-training dot-probe task were subjected to a two-way analysis of variance with two levels of session (pre and post) and two levels of group (treatment and control; **Figure 8**). All effects were statistically non-significant. The main effect of session yielded an F ratio of $F(1, 50) = 0.77$, $p > 0.05$, $eta^2 = 0.015$. The main effect of group yielded an F ratio of $F(2, 50) = 0.17$, $p > 0.05$, $eta^2 = 0.003$. The group x session interaction was also non-significant $F(1, 50) = 2.27$, $p = 0.17$, $eta^2 = 0.043$, (Treatment Group Mean AB Pre = 6.86, *S.D.* = 13.54, Post = 13.40, *S.D.* = 20.00; Control Group Mean AB Pre = 12.37, *S.D.* = 13.62, Post = 10.63, *S.D.* = 13.63).

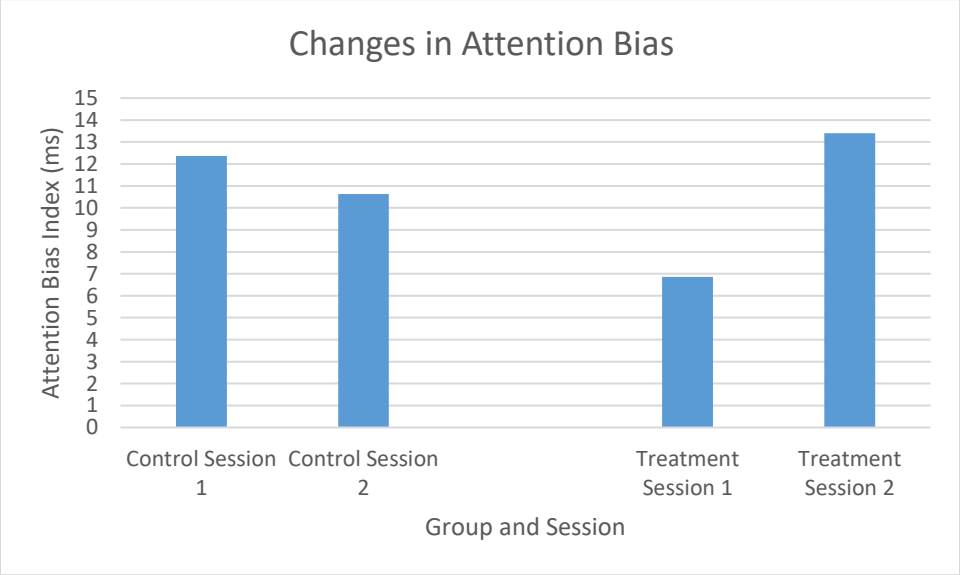


Figure 8: Changes in Attention Bias. There were no significant differences in attention bias scores between sessions or groups.

Reaction time data garnered from the pre and post-training dot-probe task was also subjected to a mixed methods analysis of variance with three levels of trial type (congruent, incongruent, and neutral), two levels of session (pre and post) and two levels of group (treatment and control). There was a main effect for trial type, $F(1, 50) = 21.55$, $p < 0.001$, $eta^2 = 0.301$, such that congruent trials ($M = 339.37$, *S.E.* = 6.91) were overall faster than incongruent trials ($M = 350.19$, *S.E.* = 6.39). There was also a main effect of session, $F(1, 50) = 16.07$, $p < 0.001$, $eta^2 = 0.243$, such that the post-training session ($M = 331.60$, *S.E.* = 7.45) was faster overall than the pre-training session ($M = 356.74$, *S.E.* = 7.36). The main effect of group was non-significant, $F(2, 50) = 1.39$, $p > 0.05$, $eta^2 = 0.003$. The trial type x group $F(1, 50) = 0.09$, $p > 0.05$, trial type x session $F(1, 50) = 0.31$, $p > 0.05$, group x session $F(1, 50) = 0.40$, $p > 0.05$, and trial type x session x group $F(1, 50) = 1.50$, $p > 0.05$ interactions were all non-significant. A further analysis was run on a cohort of participants who were highest in anxiety. In brief, the effects on attention bias were comparable to the non-clinical sample (see APPENDIX D for detailed analysis).

Hypothesis 2: The reduction in attentional bias will facilitate a reduction in anxious symptoms in the treatment group compared to baseline and the control group. STAI-S scores were subjected to a two-way analysis of variance with two levels of session (pre and post) and two levels of group (treatment and control). All effects were statistically non-significant. The main effect of session yielded an F ratio of $F(1, 47) = 1.20$, $p > 0.05$, $eta^2 = 0.025$. The main effect of group yielded an F ratio of $F(2, 47) = 0.98$, $p > 0.05$, $eta^2 = 0.020$. The group x session interaction was also non-significant $F(1, 47) = 4.05$, $p > 0.05$, $eta^2 = 0.079$ (Treatment Mean STAI-S Pre = 45.50, *S.D.* = 10.32, Post = 45.96, *S.D.* = 11.42; Control Mean STAI-S Pre = 43.70, *S.D.* = 8.72, Post = 42.13, *S.D.* = 9.62; **Figure 9**).

STAI-T scores were also subjected to a two-way analysis of variance with two levels of session (pre and post) and two levels of group (treatment and control). All effects were again statistically non-significant. The main effect of session yielded an F ratio of $F(1, 47) = 0.19$, $p > 0.05$, $eta^2 = 0.004$. The main effect of group yielded an F ratio of $F(2, 47) = 0.33$, $p > 0.05$, $eta^2 = 0.020$. The group x session interaction was also non-significant $F(1, 47) = 1.12$, $p > 0.05$, $eta^2 = 0.023$ (Treatment Mean STAI-T Pre = 46.81, *S.D.* = 13.18, Post = 47.15, *S.D.* = 14.67; Control Mean STAI-T Pre = 43.87, *S.D.* = 10.62, Post = 43.04, *S.D.* = 11.40; **Figure 9**).

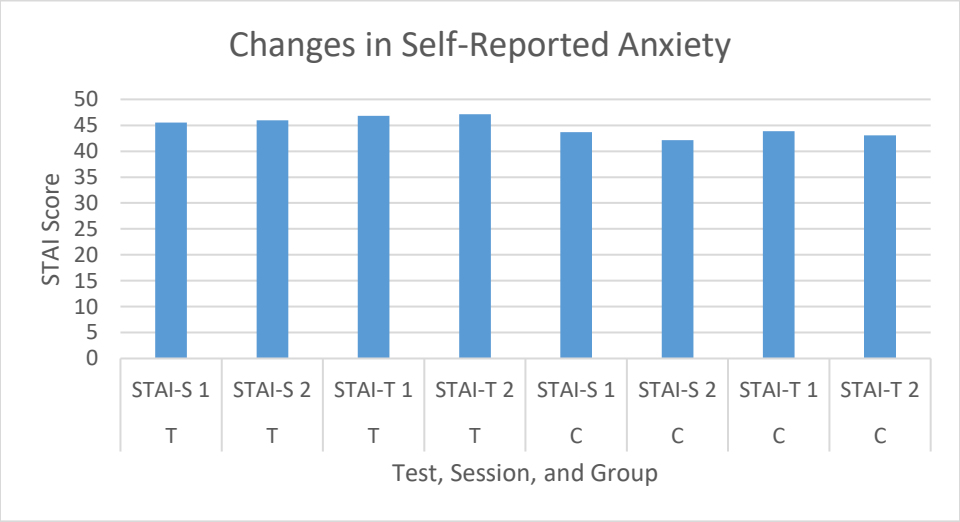


Figure 9: Changes in Self-Reported Anxiety. Anxiety levels did not differ between group or session on either the STAI-S or the STAI-T.

Hypotheses 3 & 4: ABM will result in (3) overall increased activity in the lPFC and (4) decreased activity in the mPFC after training in the treatment group, but not in the control group. Useable pre and post NIRS data was collected from 25 participants (Treatment $N = 17$;

Control $N = 8$); the rest were excluded for missing or corrupted data[1]. Results of the mixed methods ANOVA are reported here.

HbO

A mixed methods ANOVA was used to test the effects of session, group, trial type, and channel. The main effect of channel was not significant, $F(1, 23) = 1.05$, $p > 0.05$, $\text{eta}^2 = 0.044$. Nor was the main effect of trial type, $F(1, 23) = 0.06$, $p > 0.05$, $\text{eta}^2 = 0.003$. The main effect of session was also non-significant, $F(1, 23) = 1.89$, $p > 0.05$, $\text{eta}^2 = 0.076$, as was the main effect of group $F(1, 23) = 1.00$, $p > 0.05$ (**Figure 10**). The trial type x group $F(2, 23) = 0.33$, $p > 0.05$, $\text{eta}^2 = 0.001$, session x group $F(2, 23) = 2.07$, $p > 0.05$, $\text{eta}^2 = 0.082$, and trial type x session $F(2, 23) = 1.55$, $p > 0.05$, $\text{eta}^2 = 0.063$ interactions were all non-significant. The trial type x session x group interaction approached significance, $F(2, 23) = 2.78$, $p = 0.072$, $\text{eta}^2 = 0.108$, and was significant when utilizing a linear contrast, $F(2, 23) = 4.53$, $p = 0.044$, $\text{eta}^2 = 0.164$. A post-hoc pairwise comparison revealed that the control group had an overall increase in HbO during congruent trials following training (Pre = -0.001976, Post = 0.000455, $p = 0.095$) that approached significance. Incongruent (Pre = -0.001073, Post = -0.000003, $p = 0.34$) and neutral trials (Pre = -0.000576, Post = -0.000949, $p = 0.69$) did not differ in HbO between sessions (**Figure 11**).

[1] Examples of corrupted data: NIRS probe sliding during testing, computer not picking up stimulus markers, data output in the wrong format, research assistants using the wrong NIRS probe, etc.

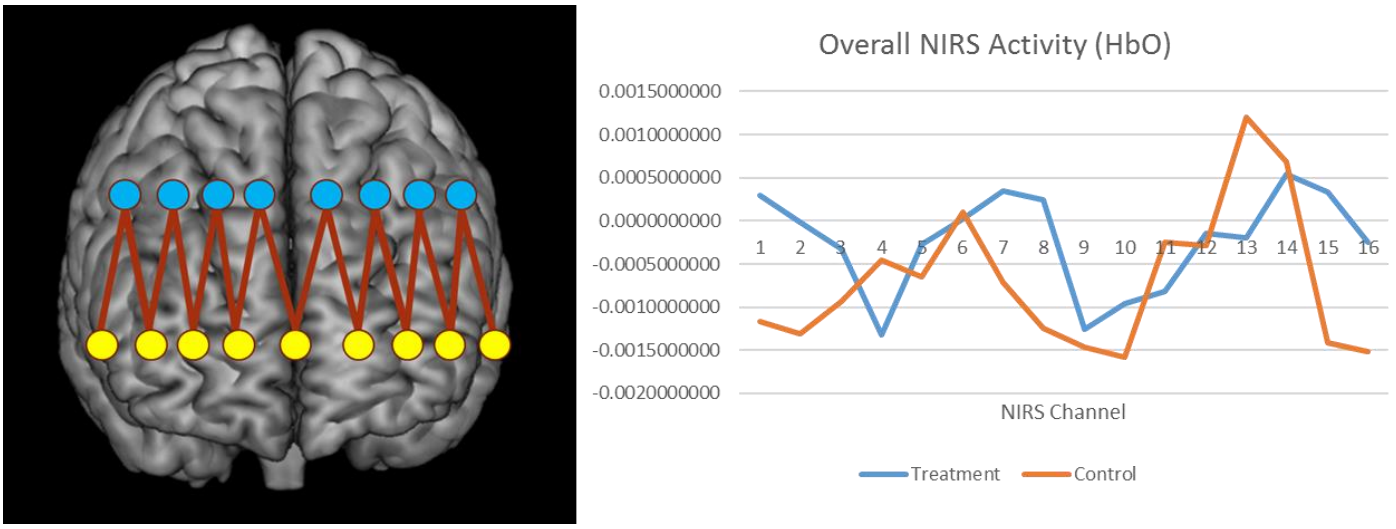


Figure 10: Overall NIRS Activity (HbO). Pictured is the averaged HbO response for each `NIRS channel for both groups.

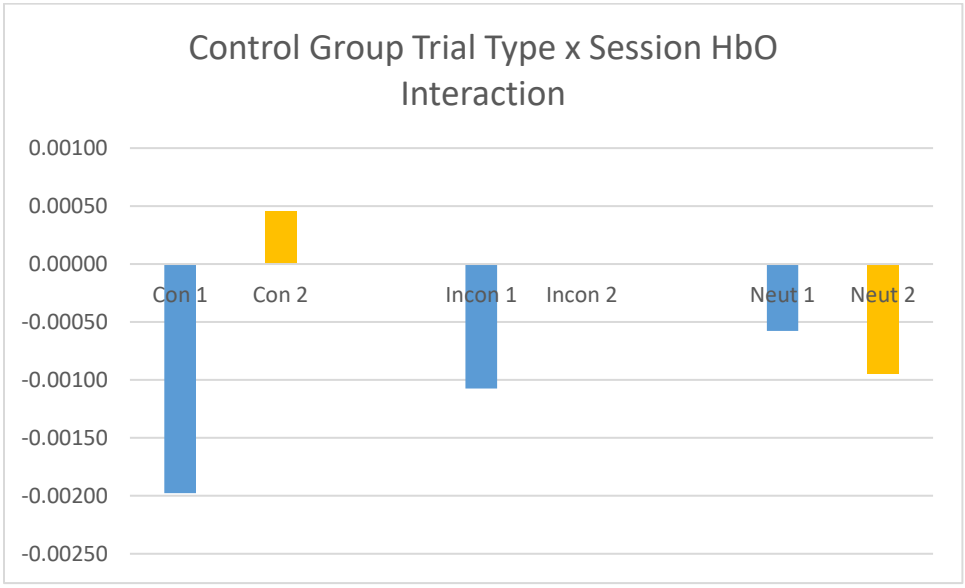


Figure 11: Control Group Trial Type x Session HbO Interaction. Prior to training, the control group had decreases in PFC activity during congruent trials; however, they had slight increases following training. The difference in activity approached significance ($p = 0.095$). Neither of the other trial types differed between sessions.

HbR

A mixed methods ANOVA was used to test the effects of session, group, trial type, and channel. The main effect of channel was not significant, $F(1, 23) = 1.09$, $p > 0.05$, $eta^2 = 0.044$. Nor was the main effect of trial type, $F(1, 23) = 0.03$, $p > 0.05$, $eta^2 = 0.001$. The main effect of session was also non-significant, $F(1, 23) = 0.02$, $p > 0.05$, $eta^2 = 0.001$, as was the main effect of group $F(1, 23) = 0.002$, $p > 0.05$ (**Figure 12**). The trial type x group $F(2, 23) = 1.01$, $p > 0.05$, $eta^2 = 0.001$, session x group $F(2, 23) = 0.28$, $p > 0.05$, $eta^2 = 0.012$, trial type x session $F(2, 23) = 0.92$, $p > 0.05$, $eta^2 = 0.063$, and the trial type x session x group interactions $F(2, 23) = 1.08$, $p > 0.05$, $eta^2 = 0.045$ were all non-significant.

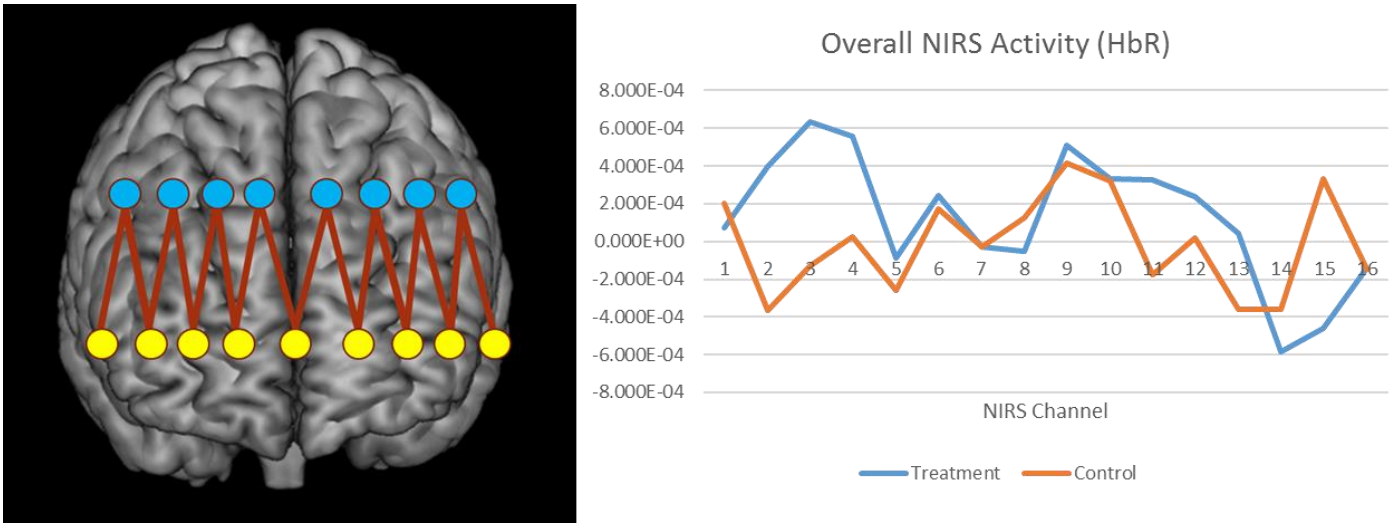


Figure 12: Overall NIRS Activity (HbR). Pictured is the averaged HbR response for each NIRS channel for both groups.

Hypothesis 5: Changes in PFC activity in response to training will be correlated with reductions in attention bias and anxious symptoms. Given that attention biases, anxious symptoms, and NIRS measures remained unchanged after training, there were no significant correlations among them, $p > 0.05$.

Supplementary Results

Given that the target appeared equally behind anxiety-related words and neutral words in the control group's training sessions, these participants were essentially just repeatedly completing a modified dot-probe task with self-relevant words. Since no studies to our knowledge have examined incorporating self-relevant words into the dot-probe task, we decided post-hoc to examine these results as well. A one-way ANOVA was used to examine the overall RT across the 6 sessions. The main effect of session was significant, $F(5, 23) = 13.21$, $p < 0.001$, $eta^2 = 0.365$, such that RT in session 1 was significantly slower than every other session (**Figure 13**), while none of the other sessions were significantly different from one another ($p > 0.05$). This suggests that participants may need to become familiarized with the task before a stable measure of attention bias can be taken. A one-way ANOVA was also run on the treatment group's training data to further assess the extent to which RT changes as a function of session. The main effect of session was significant, $F(5, 26) = 10.21$, $p < 0.001$, $eta^2 = 0.282$, such that RT in session 1 was again significantly slower than every other session (**Figure 13**), while none of the other sessions were significantly different from one another ($p > 0.05$).

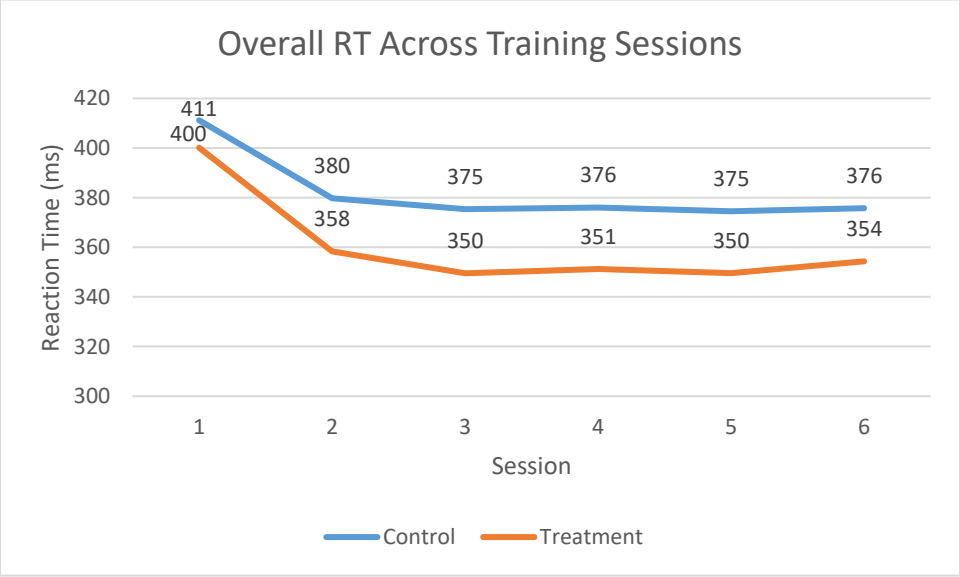
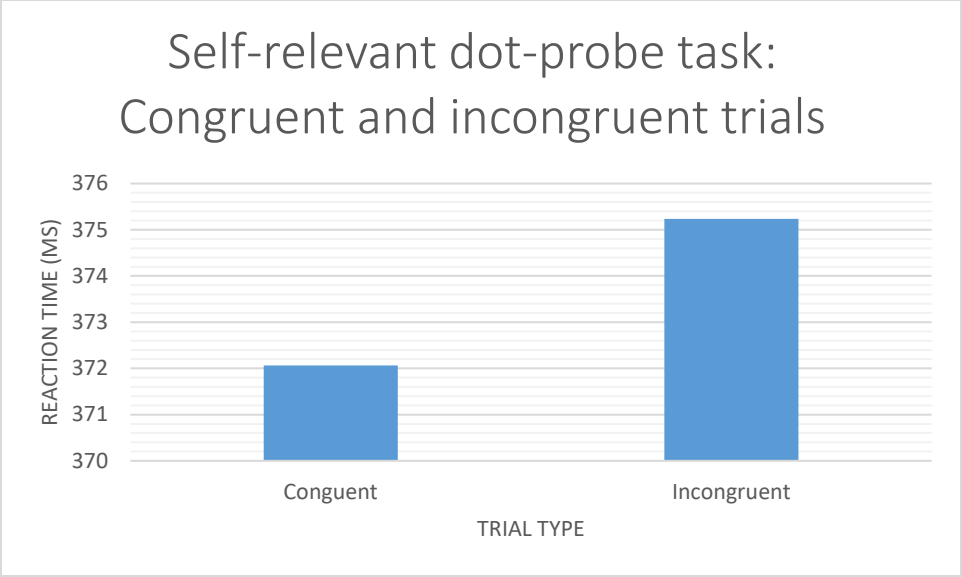


Figure 13: Self-relevant dot-probe task: Overall RT. RT in session 1 was significantly slower than all other sessions for both the treatment and control group ($p < 0.05$), suggesting that participants should become familiarized with the task before a stable measure can be taken.

When examining all 6 training sessions collapsed together, the control group did not seem to show an overall attention bias (i.e. congruent trials (M = 380.98 ms, *S.D.* = 49.95) were not significantly faster than incongruent trials (M = 383.33 ms, *S.D.* = 51.84), $t(21) = 1.86$, p = 0.08). However, given that session 1 was an outlier in that it was significantly slower than all other sessions and likely contained noise in the data just from becoming familiar with the task, we decided to remove it from our next analysis. After removing session 1, congruent trials (M = 372.07 ms, *S.D.* = 50.78) were significantly faster than incongruent (M = 375.24 ms, *S.D.* = 52.44; i.e. participants did overall demonstrate an attention bias towards their self-relevant anxiety-related words), $t(22) = -2.46$, $p = 0.02$ (**Figure 14**). A 2 x 2 ANOVA was used to test the effect of two levels of dot location (top and bottom) and two levels of trial type (congruent and incongruent) on RT across all sessions. The main effects of trial type, $F(1, 23) = 3.26$, $p > 0.05$, $\text{eta}^2 = 0.124$, and dot location, $F(1, 23) = 0.49$, $p > 0.05$, $\text{eta}^2 = 0.021$, were not significant. The trial type x dot location interaction was significant, $F(1, 23) = 5.27$, $p < 0.05$, $\text{eta}^2 = 0.186$, such that congruent trials (M = 377.53 ms, *S.E.* = 9.54) were faster than incongruent (M = 387.95 ms, *S.E.* = 11.01) when presented on top, $p = 0.01$, but not when presented on bottom (Congruent M = 384.63 ms, *S.E.* = 9.73; Incongruent M = 378.43 ms, *S.E.* = 9.54) , $p = 0.11$.

14a.



14b.

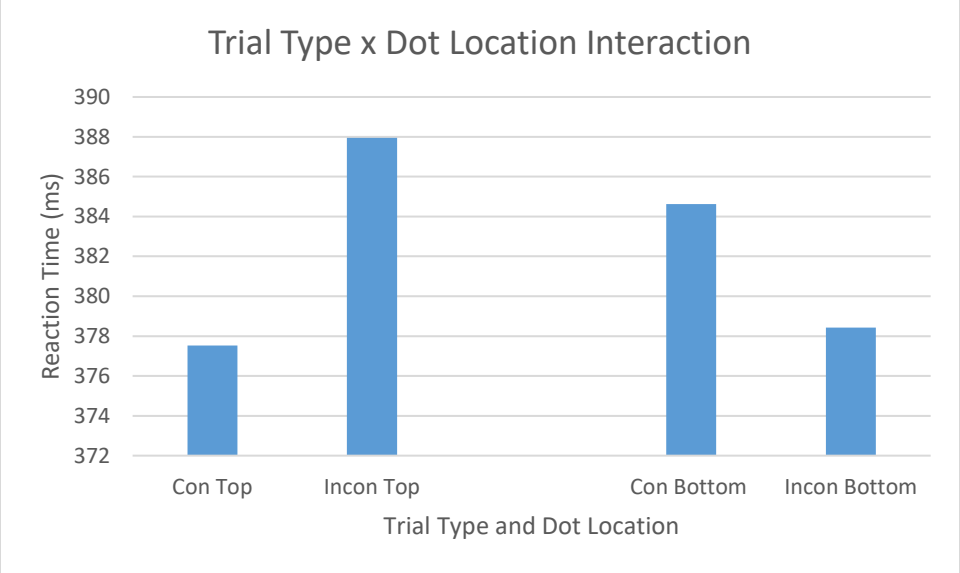
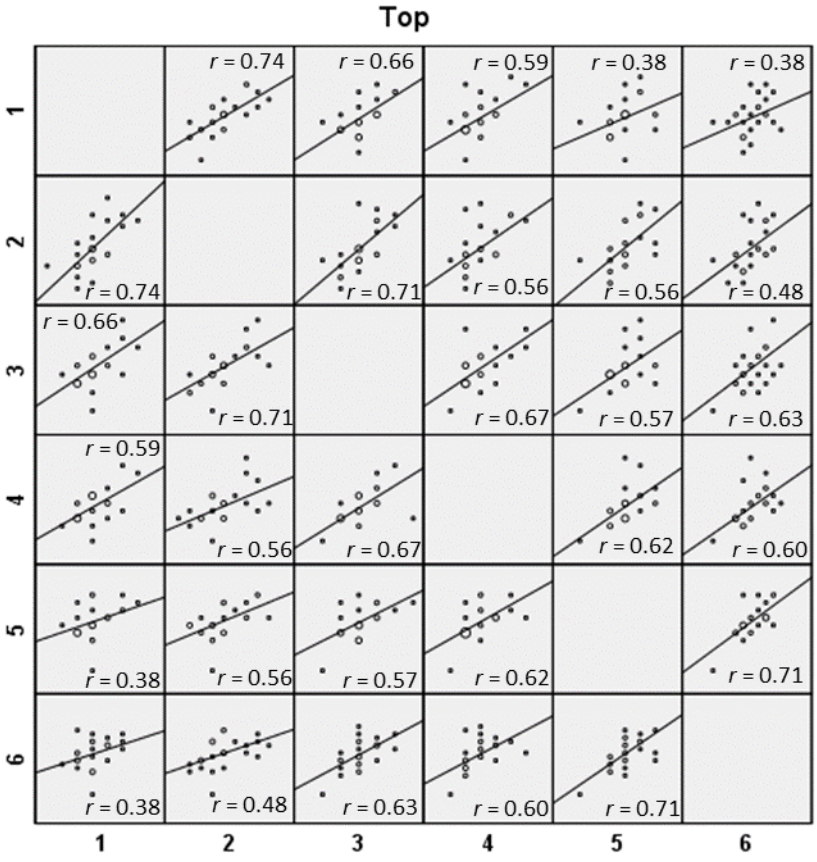


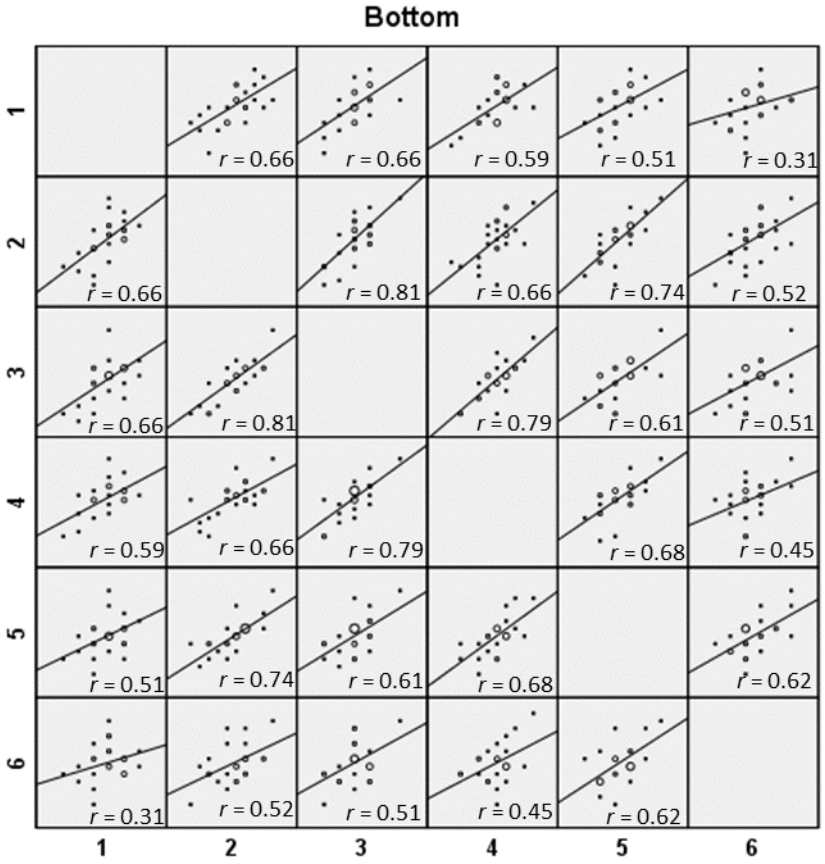
Figure 14: Self-relevant dot-probe task: Congruent and Incongruent Trials. (a) After session 1, participants responded significantly faster overall during congruent trials compared to incongruent trials ($p < 0.05$; i.e. demonstrating an attention bias). (b) However, a follow-up analysis revealed that this effect was dependent upon dot location.

We also decided to examine the test-retest reliability of the attention bias scores garnered from the self-relevant dot-probe task. Attention bias scores from sessions 2-6 were all highly correlated but contingent upon dot location. For instance, attention bias scores calculated just

from trials where the target appeared on top were highly correlated between sessions 2-6, *r*'s = 0.48-0.74, *p*'s < 0.05 (**Figure 15a**), as were attention bias scores calculated just from trials where the target appeared on bottom, *r*'s = 0.45-0.81, *p*'s < 0.05 (**Figure 15b**). Interestingly, attention bias scores calculated from top and bottom were generally negatively correlated with one another within each session, *r*'s = -0.30 to -0.94 (**Table 2**).



15a.



15b.

Figure 15: Self-relevant dot-probe task: Separate top and bottom correlations. Between sessions 2-6, attention bias scores calculated from trials in which the target appeared on top were highly correlated across sessions (15a), *r*'s = 0.48-0.74, *p*'s < 0.05, as were scores calculated from trials in which the target appeared on bottom (15b), *r*'s = 0.45-0.81, *p*'s < 0.05.

Correlations							
		Session1_BiasIndexTop	Session2_BiasIndexTop	Session3_BiasIndexTop	Session4_BiasIndexTop	Session5_BiasIndexTop	Session6_BiasIndexTop
Session1_BiasIndexBottom	Pearson Correlation	-.659**	-.661**	-.633**	-.531**	-.435*	-0.295
	Sig. (2-tailed)	0.000	0.000	0.000	0.004	0.030	0.143
	N	28	28	27	28	25	26
Session2_BiasIndexBottom	Pearson Correlation	-.591**	-.713**	-.804**	-.619**	-.690**	-.465*
	Sig. (2-tailed)	0.001	0.000	0.000	0.000	0.000	0.015
	N	28	29	28	29	26	27
Session3_BiasIndexBottom	Pearson Correlation	-.653**	-.770**	-.944**	-.700**	-.590**	-.601**
	Sig. (2-tailed)	0.000	0.000	0.000	0.000	0.002	0.001
	N	27	28	28	28	26	27
Session4_BiasIndexBottom	Pearson Correlation	-.544**	-.573**	-.706**	-.789**	-.473*	-.410*
	Sig. (2-tailed)	0.003	0.001	0.000	0.000	0.015	0.034
	N	28	29	28	29	26	27
Session5_BiasIndexBottom	Pearson Correlation	-.474*	-.487*	-.527**	-.540**	-.550**	-0.336
	Sig. (2-tailed)	0.017	0.012	0.006	0.004	0.004	0.093
	N	25	26	26	26	26	26
Session6_BiasIndexBottom	Pearson Correlation	-0.292	-0.066	-.482*	-0.315	-0.356	-.393*
	Sig. (2-tailed)	0.148	0.743	0.011	0.109	0.074	0.043
	N	26	27	27	27	26	27
**. Correlation is significant at the 0.01 level (2-tailed).							
*. Correlation is significant at the 0.05 level (2-tailed).							

Table 2. Self-relevant dot-probe task: Top and bottom correlations. Attention bias scores calculated from trials in which the target appeared on top were generally negatively correlated with trials in which the target appeared on bottom.

DISCUSSION

Summary of Results

Incorporating self-relevant stimuli into the ABM procedure does not appear to reduce attention biases or anxious symptoms in a non-clinical sample based on these results. However, PFC activity does seem to change as a function of the training. The control group had increases in PFC activity during congruent trials following training that approached significance. In addition, our supplementary analyses utilizing the control group's training sessions revealed that reaction time in session 1 was significantly slower than all other sessions, while none of the other 5 sessions differed from one another. This same trend was seen in the treatment group's training sessions as well; however, they generally responded faster than the control group's training sessions (ostensibly, because participants could implicitly begin predicting where the dot location would be in the treatment condition; i.e. behind the neutral word). Individuals do seem to show an overall attention bias when incorporating self-relevant stimuli into the dot-probe task, as evidenced by faster reaction times when the target replaced a self-relevant threat compared to a self-relevant neutral word. However, our follow-up analyses revealed that this attention bias effect only occurred in trials in which the target appeared on top. The opposite trend, which approached significance, was observed when targets appeared on bottom (i.e. participants responded faster on incongruent trials). Accordingly, attention bias scores calculated from top and bottom separately were inversely correlated with one another within each session. Lastly, this variant of the dot-probe task yielded a strikingly high measure of test-retest reliability for attention bias scores calculated from top and bottom trials separately. These findings and their implications for future research will be elaborated on next.

Effects on Attention Bias Discussion

Incorporating self-relevant stimuli into the ABM task did not reduce attention biases towards threat, as measured by the dot-probe task. It is possible that we did not see a change in the treatment group's attention bias measures simply because different types of stimuli were used during testing and training. Words were used during training sessions and faces were used during the testing sessions. Different types of stimuli were selected in order to avoid the confound of the control group being tested using the same exact task that they were repeatedly trained on, while the treatment group would've been tested on a slightly different task than they'd been trained on (i.e. the target would not be contingent with their neutral word during testing). There has been a call in recent years for studies that attempt to overcome this confound by using different stimuli during testing and training (Mogg, Waters, & Bradley, 2017). Using different types of stimuli was also justified a priori on the premise that if the goal of the training is to alter participants' attention patterns in general, then successful attention bias reduction should generalize to various stimulus types (e.g. words, faces, etc.) and not be dependent on one stimulus class. However, this may not be the case or it may be that generalization to other stimulus classes takes lengthier or more intense training. Currently, there does not seem to be a consensus in the literature regarding how much training is necessary for the treatment to be effective with treatment lengths ranging from a single session to six weeks (Bar-Heim, 2010; Aday & Carlson, in-preparation). It could also be that bias levels towards self-relevant threats are simply unrelated with attention biases towards other types of emotional stimuli (i.e. fearful faces).

It is also possible that we did not see any changes in attention bias since fewer studies have identified hypervigilance at stimulus presentation times under 200 ms compared to longer presentation times (i.e. over 500 ms; Miloff, Savva, & Carlbring, 2015). This study had words presented for 500 ms during training sessions and faces were only presented for 100 ms during

testing sessions. It is possible that the effects do not generalize as well when using different stimulus presentation times. Additionally, Torrence, Wylie, and Carlson (2017) found that attention bias scores are no longer demonstrated at longer stimulus onset asynchronies (SOA; i.e. > 300 ms), so longer facial exposure time could seemingly result in the same effect. One other possibility for the null finding is that stimuli were presented on the left and right side of the screen during testing, but on top and bottom during training. The spatial location of the target does seem to have some effect on the results, as evidenced by our supplementary results, so this is a distinct possibility. Again, however, if the training is thought to alter attention patterns in general, then we should expect to see the effect regardless of the spatial location of the stimuli.

Another factor to consider is that the treatment group did not display as robust of an attention bias at baseline as the control group- potentially leading to a floor effect. However, the treatment group's attention bias scores were not even trending down, so this is unlikely to be the only contributor to the null attention bias effects. It is also likely that there is some noise in their first attention bias score, given that our supplementary results revealed that overall reaction time does seem to change after the first time they complete a new variant of the dot-probe task. It may also be that attention biases towards self-relevant stimuli are more difficult to attenuate given the extensive history participants have with those stimuli. Lastly, it may simply be that ABM is not an effective treatment, given that the existing literature is fairly inconsistent and potentially contaminated by publication bias. Hallion and Ruscio (2011) found that after accounting for publication bias using a trim-and-fill procedure, ABM had no effect on anxious symptoms in their meta-analysis. However, given the fairly extensive ABM literature, it seems likely that researchers just need to continue to refine protocols to determine whom it is most effective for, rather than it being a sham training. To date, the protocols and populations included in ABM

studies have varied dramatically; a consensus on effective pre-training assessment measures and precisely defined experimental protocols would likely result in more consistent findings across studies. The null group results should perhaps be unsurprising in light of a recent expansive review of ABM, which reported that most ABM studies have found comparable reductions in attention bias scores between control and ABM training, even when self-reported anxiety is reduced (Mogg, Waters, & Bradley, 2017).

Effects on Self-Reported Anxiety Discussion

The use of self-relevant stimuli also did not seem to affect self-reported anxiety levels, as measured by the STAI-S and STAI-T. It is possible that the use of a non-clinical sample may have led to a floor effect with their anxiety levels; participants who aren't clinically anxious to begin with do not have as much room for improvement in their anxiety levels as those who are. Moreover, a moderate level of anxiety is beneficial in many situations (e.g. making deadlines, escaping threatening situations, performing under pressure, etc.), so the effects of the training may not be beneficial to those without maladaptive anxiety. It is possible that changes in state anxiety were not observed because of the low-stress nature of the laboratory environment. It may be that the anxiolytic benefits from ABM are only demonstrated in stressful situations or in instances of high state anxiety. Again, in light of the recent illuminating review by Mogg, Waters, and Bradley (2017), the lack of change in self-reported anxiety should perhaps be unsurprising given that only 9 out of 32 studies they reviewed showed differences between ABM and control training on anxiety levels.

Effects on NIRS Measures Discussion

The training did not seem to yield robust changes in brain activity, which is somewhat unsurprising given that we did not see any changes between our pre and post-testing behavioral measures. We did find that the control group demonstrated an overall increase in HbO in the PFC during congruent trials following training that approached significance. The increases in PFC activity may have risen through increased attentional control. A recent review has noted that in many ABM studies, the control group has comparable reductions in anxiety (Mogg, Waters, & Bradley, 2017). It may be that anxiety arises from a combination of inadequate top-down goal-directed inhibitory control and overreliance on bottom-up stimulus evaluation/detection. In this view, both training methods would provide benefit as each involve extensive time spent using the top-down goal-directed inhibitory system during threat cue exposure. The benefits seen in ABM might not stem from directing attention away from threat, but rather from becoming better at engaging the top-down goal-directed inhibitory system, which seems to be practiced to some degree in both tasks (Mogg, Waters, & Bradley, 2017). Contingently directing attention away from threat may provide little additional benefits or may only benefit certain populations.

Conversely, it may also be possible that contingently directing attention towards the neutral stimulus could result in a lack of top-down attention over time as participants shift to a more bottom-up strategy, relying on the stimulus features to direct their attention. In this view, the two methods operate on distinct aspects of attention. The control training likely improves top-down goal-directed inhibitory control as participants must use that system to disengage from the salient threat, and the treatment group benefits from orienting their attention away threat specifically. This may explain why most studies have seen reductions in anxiety in both groups- they are likely benefitting through separate mechanisms. Thus, the treatment and control training may target different aspects of attention and benefit distinct populations. In this view, it would

seem that the control variant would improve delayed disengagement, as those participants still orient towards threat but practice disengaging on half the trials, and the treatment variant would improve facilitated orienting, as those participants over time would ostensibly no longer orient towards the threat after locating the neutral stimulus. Since we did not include neutral-neutral trials in the self-relevant dot-probe task, we were unable to isolate delayed disengagement and facilitated orienting effects to confirm this hypothesis. If the control training did result in greater top-down control, this may partly explain why that group showed increases in PFC activity during threat exposure, as that region is well-known for its role in top-down processes such as emotion regulation and cognitive control (Aday, Rizer, & Carlson, 2017).

Supplementary Results Discussion

The control group's training sessions yielded perhaps the most interesting and meaningful results from the experiment. Again, since the target was not contingent with the neutral word during their training, these participants were essentially just repeatedly completing a standard dot-probe task with self-relevant words rather than going through ABM. The results indicate that the overall RT in session 1 is slower than every other session, while the other 5 sessions were not statistically different from one another. This implies that participants may need to become familiar with the task before a stable measure of attention bias can be taken. This claim was corroborated by a follow-up analysis that revealed that the treatment group also responded significantly slower in session 1 compared to the other 5 sessions, which did not differ from one another. The RTs from session 1 are likely contaminated by factors other than our independent variable, such as just getting used to the experimental apparatus. This may explain why we did not see an overall difference between congruent and incongruent trials before

removing session 1 from the analysis. Future studies should consider including a pre-testing practice period in order to increase reliability and minimize noise in the data.

Utilizing self-relevant stimuli in the dot-probe task also seems to yield a strikingly higher test-retest reliability than traditional dot-probe studies (Schmukle, 2005). The dot-probe task has been criticized in the past for having poor test-retest reliability with correlation coefficients ranging from 0 to 0.30. Improving the test-retest reliability of the task is of considerable importance given its increasing prevalence as a psychometric instrument (Price et al., 2015). When looking at the overall bias index within each session, our results were comparable to previous findings showing little to no correlation between sessions. However, when calculating bias scores from just top trials and then just bottom-target trials separately, we found that these scores were incredibly consistent across sessions 2-6, with *r* values ranging from 0.45 to 0.81 (**Figure 15**). This effect can be explained in part by our follow-up finding that overall, the participants demonstrated an attention bias on top-sided trials but not on bottom-sided trials. It is possible that participants may have been more inclined to direct their attention towards the top of the screen than the bottom since they were presented with words and individuals typically start at the top of the document when reading rather than the bottom. However, there was no main effect for dot location so this likely isn't the only contributing factor. Future studies should examine the extent to which the test-retest reliability of the dot-probe task is dependent on dot location. It is currently unclear if our relatively high test-retest reliability is due to the inclusion of self-relevant words or if it's because the vast majority of previous researchers have not considered the spatial location of the target in the calculation of their attention bias scores.

To the best of my knowledge, there has only been a single study in which attention bias scores were calculated separately for top and bottom trials (Price et al., 2015). These researchers

had socially anxious participants complete a dot-probe task 12 different times using emotional and neutral facial expressions presented in a vertical orientation. The researchers generally found that attention bias scores garnered from bottom trials (*r*'s between 0.5-0.6) were much more reliable than scores calculated from top or when combining top and bottom trials. In contrast, the test-retest reliability of attention bias scores calculated from top (averaged $r = 0.61$ for sessions 2-6) and bottom (averaged $r = 0.64$ for sessions 2-6) were comparable in my study and considerably higher than traditional test-retest measures. It could be that since faces were presented in a vertical orientation in the Price et al. (2015) study, participants were more inclined to attend the bottom half of the screen since the eyes of the face would be closer to the fixation cue and it has been shown that fearful eyes themselves capture attention (Carlson, Torrence, Vander Hyde, 2016). This may have led to more reliable results on bottom-target trials compared to top; an effect that wouldn't be seen in the current study since words were presented. Price et al. (2015) noted that measures of attention bias variability (ABV) were more stable in their study than the traditional method of collecting attention bias indices (i.e. incongruent RT – congruent RT). ABV is calculated by "binning" the data from each session into sequential sets then calculating the standard deviation and dividing by the overall RT. ABV is thought to yield a more dynamic measure of attention bias that accounts for fluctuations certain populations may have between threat-avoidance and hypervigilance. Attention biases may be less stable than initially believed and susceptible to mood and environmental influences; thus, ABV may yield a more valid measure of attention bias. Future analyses with this dataset should examine the extent to which the test-retest reliability of ABV fluctuates across sessions when incorporating self-relevant stimuli.

Limitations

There are several notable limitations that must be considered in drawing conclusions from the results in this study. First, a non-clinical sample was used to assess the effects of the anxiolytic treatment. It is possible, and perhaps inevitable, that anxious and non-anxious individuals may respond differently to the treatment. All individuals have some level of anxiety, but it is possible that floor effects may have prevented the intervention from lowering anxiety further. Another limitation is the stimuli differed between testing and training. It is possible that we would have seen more robust effects if we used the same stimuli; however, we hoped to avoid the confound of the control group's testing task being identical to their training task, which wouldn't have been the case for the treatment group. It is also difficult to assess the degree to which our results were due specifically to the inclusion of self-relevant stimuli as we did not have a group assigned to experimenter-generated words. However, due to a limited sample and resources, we decided to only include our treatment and control group with self-relevant words rather than further diluting our sample sizes. Another limitation regards the neuroimaging equipment; NIRS is limited in that in can only measure activity in the first centimeter of the cortex as it uses light, which is quickly scattered. The significant amount of NIRS data lost to equipment errors and corrupted files may also limit these results as the difficulties hindered sample sizes and reduced power.

Directions for Future Research

Future research should examine the extent to which incorporating self-relevant stimuli into ABM training changes treatment outcomes across various populations. The extent to which changes in attention bias generalize across stimulus classes (e.g. faces, words, pictures, etc.) and how long that may take also remains an important and unanswered question in the ABM literature. It may be fruitful to use tests other than the dot-probe task to assess the extent to which

the changes in attention bias generalize or are task-specific. Further elucidating which aspects of attention the treatment and control variants of ABM differentially operate on is also of critical importance in order to identify which populations may benefit most from the training. Most pertinent to this study, future researchers should explore a direct comparison between self-relevant and experimenter-generated stimuli. Future research should also consider including neuroimaging methodologies, other than NIRS, that have the capacity to measure other areas of high interest such as the ACC and amygdala (Carlson et al., 2012; Carlson, Cha, Harmon-Jones, Mujica-Parodi, Hajcak, 2014). Based off the results of several studies (Price et al., 2015; Badura-Brack et al., 2015), it may be fruitful to examine how ABV changes across training when incorporating self-relevant stimuli as well.

Conclusion

To conclude, it is difficult to make definitive statements regarding the efficacy of incorporating self-relevant stimuli into ABM training based solely off these results. Our study suggests that their inclusion does not reduce attention biases or anxiety, at least in a non-clinical sample. The control variant of the task seems to lead to increases in HbO following training in the PFC during congruent trials. Interpretation of this finding isn't perfectly clear, but previous research suggests that the changes in brain activity may relate to changes in attentional control and top-down processing. While their inclusion did not seem to facilitate anxiolytic effects, using self-relevant stimuli in the dot-probe task did generate several notable results. First, RT stabilizes in the dot-probe task after an initial session. This suggests that there may be noise in the data when participants complete the task for the first time. This may explain some of the previous inconsistent findings regarding the task and should inform future methodology. Second, individuals do seem to overall show an attention bias towards their self-relevant threats when

used in the task. However, this effect is unique to trials in which the target appears on top and the data trends towards participants being threat-avoidant rather than hypervigilant on bottom-target trials. Accordingly, bias scores calculated from top and bottom within each session are negatively correlated with one another. Attention bias scores garnered from solely top-target trials are highly correlated across sessions as are scores calculated just from bottom-target trials. However, it is unclear if the relatively high test-retest reliability is due to the inclusion of self-relevant stimuli or simply because very few previous researchers have thought to interpret their bias indexes in relation to the spatial location of the dot. Future research should explore both possibilities in addition to the many other questions that remain regarding the efficacy of using self-relevant stimuli in the dot-probe task and ABM training.

References

Aday, J.S. & Carlson, J.M. (in-preparation). Structural MRI-based measures of neuroplasticity in an extended amygdala network as a target for attention bias modification treatment outcome.

Aday, J.S., Rizer, W., & Carlson, J.M. (2017). Neural mechanisms of emotions and affect. In Jeon, M. (Eds.), *Emotions and Affect in Human Factors and Human-Computer Interaction* (pp. 27-87). San Diego, California: Academic Press.

Adolphs, R. (2004). Emotional vision. *Nature Neuroscience, 7*(11), 1167-1168. doi:10.1038/nn1104-1167

Adolphs, R., Gosselin, F., Buchanan, T. W., Tranel, D., Schyns, P., & Damasio, A. R. (2005). A mechanism for impaired fear recognition after amygdala damage. *Nature, 433*(7021), 68-72. doi:10.1038/nature03086

Adolphs, R., Tranel, D., Hamann, S., Young, A., Calder, A., Phelps, E., Anderson, A., Lee, G.P., & Damasio, A. (1999). Recognition of facial emotion in nine individuals with bilateral amygdala damage.*Neuropsychologia, 37*(10), 1111-1117. doi:10.1016/s0028-3932(99)00039-1

Amir, N., Taylor, C. T., & Donohue, M. C. (2011). Predictors of response to an attention modification program in generalized social phobia. *Journal of Consulting and Clinical Psychology, 79*(4), 533-541. doi:10.1037/a0023808

Badura-Brack, A. S., Naim, R., Ryan, T. J., Levy, O., Abend, R., Khanna, M. M., … Bar-Haim, Y. (2015). Effect of Attention Training on Attention Bias Variability and PTSD Symptoms: Randomized Controlled Trials in Israeli and U.S. Combat

Veterans. *American Journal of Psychiatry*, *172*(12), 1233-1241. doi:10.1176/appi.ajp.2015.14121578

Ballenger, J. C. (2004). Remission Rates in Patients With Anxiety Disorders Treated With Paroxetine. *J. Clin. Psychiatry*, *65*(12), 1696-1707. doi:10.4088/jcp.v65n1216

Bar-Haim, Y. (2010). Research Review: attention bias modification (ABM): a novel treatment for anxiety disorders. *Journal of Child Psychology and Psychiatry*, *51*(8), 859-870. doi:10.1111/j.1469-7610.2010.02251.x

Bar-Haim, Y., Lamy, D., Pergamin, L., Bakermans-Kranenburg, M. J., & Van IJzendoorn, M. H. (2007). Threat-related attentional bias in anxious and nonanxious individuals: A meta-analytic study. *Psychological Bulletin*, *133*(1), 1-24. doi:10.1037/0033-2909.133.1.1

Barlow, D. H., Gorman, J. M., Shear, M. K., & Woods, S. W. (2000). Cognitive-Behavioral Therapy, Imipramine, or Their Combination for Panic Disorder. *JAMA, 283*(19), 2529. doi:10.1001/jama.283.19.2529

Beard, C. (2011). Cognitive bias modification for anxiety: current evidence and future directions. *Expert Review of Neurotherapeutics*, *11*(2), 299-311. doi:10.1586/ern.10.194

Beard, C., Sawyer, A. T., & Hofmann, S. G. (2012). Efficacy of Attention Bias Modification Using Threat and Appetitive Stimuli: A Meta-Analytic Review. *Behavior Therapy*,*43*(4), 724-740. doi:10.1016/j.beth.2012.01.002

Boas, D., & Franceschini, M. (2009). Near infrared imaging. *Scholarpedia*, *4*(4), 6997. doi:10.4249/scholarpedia.6997

Borkovec, T. D., & Costello, E. (1993). Efficacy of applied relaxation and cognitive-behavioral therapy in the treatment of generalized anxiety disorder. *Journal of Consulting and Clinical Psychology, 61*(4), 611-619. doi:10.1037//0022-006x.61.4.611

Botvinick, M., Nystrom, L. E., Fissell, K., Carter, C. S., & Cohen, J. D. (1999). Conflict monitoring versus selection-for-action in anterior cingulate cortex. *Nature,* 402(6758), 179-181.

Bradley, M.M., & Lang, P.J. (1999). Affective norms for English words (ANEW): Instruction manual and affective ratings. Technical Report C-1, The Center for Research in Psychophysiology, University of Florida.

Bradley, B. P., Mogg, K., White, J., Groom, C., & Bono, J. (1999). Attentional bias for emotional faces in generalized anxiety disorder. *British Journal of Clinical Psychology*,*38*(3), 267-278. doi:10.1348/014466599162845

Brenes, G. A., Penninx, B. W., Judd, P. H., Rockwell, E., Sewell, D. D., & Wetherell, J. L. (2008). Anxiety, depression and disability across the lifespan. *Aging & Mental Health, 12*(1), 158-163. doi:10.1080/13607860601124115

Britton, J. C., Suway, J. G., Clementi, M. A., Fox, N. A., Pine, D. S., & Bar-Haim, Y. (2015). Neural changes with attention bias modification for anxiety: a randomized trial. *Soc Cogn Affect Neurosci, 10*(7), 913-920. doi:10.1093/scan/nsu141

Browning, M., Holmes, E. A., & Harmer, C. J. (2010). The modification of attentional bias to emotional information: A review of the techniques, mechanisms, and relevance to emotional disorders. *Cognitive, Affective, & Behavioral Neuroscience*, *10*(1), 8-20. doi:10.3758/cabn.10.1.8

Burle, B., Spieser, L., Roger, C., Casini, L., Hasbroucq, T., & Vidal, F. (2015). Spatial and temporal resolutions of EEG: Is it really black and white? A scalp current density view.*International Journal of Psychophysiology*, *97*(3), 210-220. doi:10.1016/j.ijpsycho.2015.05.004

Bystritsky, A., Hovav, S., Sherbourne, C., Stein, M. B., Rose, R. D., Campbell-Sills, L., Golinelli, D., Sullivan, G., Crask, M.G., & Roy-Byrne, P. P. (2012). Use of Complementary and Alternative Medicine in a Large Sample of Anxiety Patients. *Psychosomatics*, *53*(3), 266-272. doi:10.1016/j.psym.2011.11.009

Bystritsky, A., Khalsa, S. S., Cameron, M. E., & Schiffman, J. (2013). Current diagnosis and treatment of anxiety disorders. *PT*, *38*(1), 30-57.

Carlson, J. M., Beacher, F., Reinke, K. S., Habib, R., Harmon-Jones, E., Mujica-Parodi, L. R., & Hajcak, G. (2012). Nonconscious attention bias to threat is correlated with anterior cingulate cortex gray matter volume: A voxel-based morphometry result and replication.*NeuroImage*, *59*(2), 1713-1718. doi:10.1016/j.neuroimage.2011.09.040

Carlson, J. M., Cha, J., Harmon-Jones, E., Mujica-Parodi, L. R., & Hajcak, G. (2014). Influence of the BDNF Genotype on Amygdalo-Prefrontal White Matter Microstructure is Linked to Nonconscious Attention Bias to Threat. *Cerebral Cortex*, *24*(9), 2249-2257. doi:10.1093/cercor/bht089

Carlson, J. M., & Mujica-Parodi, L. R. (2014). Facilitated Attentional Orienting and Delayed Disengagement to Conscious and Nonconscious Fearful Faces. *J Nonverbal Behav*,*39*(1), 69-77. doi:10.1007/s10919-014-0185-1

Carlson, J. M., & Reinke, K. S. (2008). Masked fearful faces modulate the orienting of covert spatial attention. *Emotion*, *8*(4), 522-529. doi:10.1037/a0012653

Carlson, J. M., & Reinke, K. S. (2010). Spatial attention-related modulation of the N170 by backward masked fearful faces. *Brain and Cognition*, *73*(1), 20-27. doi:10.1016/j.bandc.2010.01.007

Carlson, J. M., Reinke, K. S., & Habib, R. (2009). A left amygdala mediated network for rapid orienting to masked fearful faces. *Neuropsychologia*, *47*(5), 1386-1389. doi:10.1016/j.neuropsychologia.2009.01.026

Carlson, J. M., Reinke, K. S., LaMontagne, P. J., & Habib, R. (2010). Backward masked fearful faces enhance contralateral occipital cortical activity for visual targets within the spotlight of attention. *Soc Cogn Affect Neurosci*, *6*(5), 639-645. doi:10.1093/scan/nsq076

Carlson, J. M., Torrence, R. D., & Vander Hyde, M. R. (2016). Beware the eyes behind the mask: The capture and hold of selective attention by backward masked fearful eyes. *Motivation and Emotion*, *40*(3), 498-505. doi:10.1007/s11031-016-9542-1

Cartwright-Hatton, S., Roberts, C., Chitsabesan, P., Fothergill, C., & Harrington, R. (2004). Systematic review of the efficacy of cognitive behaviour therapies for childhood and adolescent anxiety disorders. *British Journal of Clinical Psychology*, *43*(4), 421-436. doi:10.1348/0144665042388928

Cascade, E., Kalali, A. H., & Kennedy, S. H. (2009). Real-World data on SSRI antidepressant side effects. *Psychiatry (Edgmont)*, *6*(2), 16–18.

Eldar, S., & Bar-Haim, Y. (2009). Neural plasticity in response to attention training in anxiety. *Psychological Medicine*, *40*(04), 667. doi:10.1017/s0033291709990766

Gur, R. C., Sara, R., Hagendoorn, M., Marom, O., Hughett, P., Macy, L., Turner, T., Bajcsy, R., Posner, A., & Gur, R. E. (2002). A method for obtaining 3-dimensional facial

expressions and its standardization for use in neurocognitive studies. *Journal of Neuroscience Methods*, *115*(2), 137-143. doi:10.1016/s0165-0270(02)00006-7

Hakamata, Y., Lissek, S., Bar-Haim, Y., Britton, J. C., Fox, N. A., Leibenluft, E., Ernst, M., & Pine, D. S. (2010). Attention bias modification treatment: A meta-analysis toward the establishment of novel treatment for anxiety. *Biological Psychiatry*, *68*(11), 982-990. doi:10.1016/j.biopsych.2010.07.021

Hallion, L. S., & Ruscio, A. M. (2011). A meta-analysis of the effect of cognitive bias modification on anxiety and depression. *Psychological Bulletin*, *137*(6), 940-958. doi:10.1037/a0024355

Heeren, A., Philippot, P., & Koster, E. H. (2015). Impact of the temporal stability of preexistent attentional bias for threat on its alteration through attention bias modification. *Journal of Behavior Therapy and Experimental Psychiatry*, *49*, 69-75. doi:10.1016/j.jbtep.2014.10.012

Hertel, P. T., & Mathews, A. (2011). Cognitive Bias Modification: Past Perspectives, Current Findings, and Future Applications. *Perspectives on Psychological Science*, *6*(6), 521-536. doi:10.1177/1745691611421205

Hettema, J. M., Neale, M. C., & Kendler, K. S. (2001). A Review and Meta-Analysis of the Genetic Epidemiology of Anxiety Disorders. *American Journal of Psychiatry*, *158*(10), 1568-1578. doi:10.1176/appi.ajp.158.10.1568

Hirschfield, R. M. (2001). The Comorbidity of Major Depression and Anxiety Disorders. *Prim. Care Companion J. Clin. Psychiatry*, *03*(06), 244-254. doi:10.4088/pcc.v03n0609

Hoffman, D. L., Dukes, E. M., & Wittchen, H. (2008). Human and economic burden of generalized anxiety disorder. *Depression and Anxiety*, *25*(1), 72-90. doi:10.1002/da.20257

Jorm, A. F. (2000). Does old age reduce the risk of anxiety and depression? A review of epidemiological studies across the adult life span. *Psychological Medicine*, *30*(1), 11-22. doi:10.1017/s0033291799001452

Kaufman, J., & Charney, D. (2000). Comorbidity of mood and anxiety disorders. *Depression and Anxiety*, *12*(S1), 69-76. doi:10.1002/1520-6394(2000)12:1+<69::aid-da9>3.0.co;2-k

Kessler, R. C., Soukup, J., Davis, R. B., Foster, D. F., Wilkey, S. A., Van Rompay, M. I., & Eisenberg, D. M. (2001). The Use of Complementary and Alternative Therapies to Treat Anxiety and Depression in the United States. *American Journal of Psychiatry*, *158*(2), 289-294. doi:10.1176/appi.ajp.158.2.289

Kessler, R. C., Chiu, W. T., Demler, O., & Walters, E. E. (2005). Prevalence, Severity, and Comorbidity of 12-Month DSM-IV Disorders in the National Comorbidity Survey Replication. *Arch Gen Psychiatry*, *62*(6), 617. doi:10.1001/archpsyc.62.6.617

Kinrys, G., & Wygant, L. E. (2005). Anxiety disorders in women: does gender matter to treatment? *Rev. Bras. Psiquiatr*, *27*, s43-s50. doi:10.1590/s1516-44462005000600003

Koster, E. H., Crombez, G., Verschuere, B., & De Houwer, J. (2004). Selective attention to threat in the dot probe paradigm: differentiating vigilance and difficulty to disengage. *Behaviour Research and Therapy*, *42*(10), 1183-1192. doi:10.1016/j.brat.2003.08.001

Kuckertz, J. M., & Amir, N. (2015). Attention Bias Modification for Anxiety and Phobias: Current Status and Future Directions. *Current Psychiatry Reports*, *17*(2). doi:10.1007/s11920-014-0545-x

Kuckertz, J. M., Gildebrant, E., Liliequist, B., Karlström, P., Väppling, C., Bodlund, O., Stenlund, T., Hofmann, S., Andersson, G., Amir, N., & Carlbring, P. (2014). Moderation and mediation of the effect of attention training in social anxiety disorder. *Behaviour Research and Therapy, 53,* 30-40. doi:10.1016/j.brat.2013.12.003

Lewinsohn, P. M., Gotlib, I. H., Lewinsohn, M., Seeley, J. R., & Allen, N. B. (1998). Gender differences in anxiety disorders and anxiety symptoms in adolescents. *Journal of Abnormal Psychology*, *107*(1), 109-117. doi:10.1037/0021-843x.107.1.109

Logothetis, N. K., Pauls, J., Augath, M., Trinath, T., & Oeltermann, A. (2001). Neurophysiological investigation of the basis of the fMRI signal. *Nature,* 412(6843), 150-157.

Longo, L. P., & Johnson, B. (2000). Addiction: Part I. Benzodiazepines-side effects, abuse risk and alternatives. *American family physician*, *61*(7), 2121-2128.

MacLeod, C., & Mathews, A. (1988). Anxiety and the allocation of attention to threat. *The Quarterly Journal of Experimental Psychology Section A*, *40*(4), 653-670. doi:10.1080/14640748808402292

MacLeod, C., & Mathews, A. (2012). Cognitive Bias Modification Approaches to Anxiety. *Annual Review of Clinical Psychology*, *8*(1), 189-217. doi:10.1146/annurev-clinpsy-032511-143052

MacLeod, C., Mathews, A., & Tata, P. (1986). Attentional bias in emotional disorders. *Journal of Abnormal Psychology*, *95*(1), 15-20. doi:10.1037/0021-843x.95.1.15

MacCleod, C., Soong, L. Y., Rutherford, E. M., & Campbell, L. W. (2007). Internet-delivered assessment and manipulation of anxiety-linked attentional bias: Validation of a free-

access attentional probe software package. *Behavior Research Methods*, *39*(3). doi:10.3758/BF03193023

MacLeod, C., Rutherford, E., Campbell, L., Ebsworthy, G., & Holker, L. (2002). Selective attention and emotional vulnerability: Assessing the causal basis of their association through the experimental manipulation of attentional bias. *Journal of Abnormal Psychology*, *111*(1), 107-123. doi:10.1037//0021-843x.111.1.107

McLean, C. P., Asnaani, A., Litz, B. T., & Hofmann, S. G. (2011). Gender differences in anxiety disorders: Prevalence, course of illness, comorbidity and burden of illness. *Journal of Psychiatric Research*, *45*(8), 1027-1035. doi:10.1016/j.jpsychires.2011.03.006

Mehagnoul-Schipper, D. J., Van der Kallen, B. F., Colier, W. N., Van der Sluijs, M. C., Van Erning, L. J., Thijssen, H. O., Oeseburb, B., Hoefnagels, W.H., & Jansen, R. W. (2002). Simultaneous measurements of cerebral oxygenation changes during brain activation by near-infrared spectroscopy and functional magnetic resonance imaging in healthy young and elderly subjects. *Human Brain Mapping*, *16*(1), 14. doi:10.1002/hbm.10026.abs

Miloff, A., Savva, A., & Carlbring, P. (2015). Cognitive bias measurement and social anxiety disorder: Correlating self-report data and attentional bias. *Internet Interventions*, *2*(3), 227-234. doi:10.1016/j.invent.2015.03.006

Mogg, K., Bradley, B. P., & Hallowell, N. (1994). Attentional bias to threat: Roles of trait anxiety, stressful events, and awareness. *The Quarterly Journal of Experimental Psychology Section A*, *47*(4), 841-864. doi:10.1080/14640749408401099

Mogg, K., Bradley, B. P., & Williams, R. (1995). Attentional bias in anxiety and depression: The role of awareness. *British Journal of Clinical Psychology*, *34*(1), 17-36. doi:10.1111/j.2044-8260.1995.tb01434.x

Mogg, K., Mathews, A., & Eysenck, M. (1992). Attentional bias to threat in clinical anxiety states. *Cognition & Emotion*, *6*(2), 149-159. doi:10.1080/02699939208411064

Mogg, K., Mathews, A., & Weinman, J. (1987). Memory bias in clinical anxiety. *Journal of Abnormal Psychology*, *96*(2), 94-98. doi:10.1037/0021-843x.96.2.94

Mogg, K., Waters, A. M., & Bradley, B. P. (2017). Attention Bias Modification (ABM): Review of Effects of Multisession ABM Training on Anxiety and Threat-Related Attention in High-Anxious Individuals. *Clinical Psychological Science*, 216770261769635. doi:10.1177/2167702617696359

Mogoaşe, C., David, D., & Koster, E. H. (2014). Clinical Efficacy of Attentional Bias Modification Procedures: An Updated Meta-Analysis. *Journal of Clinical Psychology*,*70*(12), 1133-1157. doi:10.1002/jclp.22081

Nielsen, F. Å. (2011). A new ANEW: Evaluation of a word list for sentiment analysis in microblogs. *arXiv preprint arXiv:1103.2903*.

Noyes, R. J., & Hoehn-Saric, R. (1998). The Anxiety Disorders. doi:10.1017/cbo9780511663222

Obrig, H., Wenzel, R., Kohl, M., Horst, S., Wobst, P., Steinbrink, J., … Villringer, A. (2000). Near-infrared spectroscopy: does it function in functional activation studies of the adult brain? *International Journal of Psychophysiology*, *35*(2-3), 125-142. doi:10.1016/s0167-8760(99)00048-3

Peck, C. J., Lau, B., & Salzman, C. D. (2013). The primate amygdala combines information about space and value. *Nature Neuroscience, 16*(3), 340-348. doi:10.1038/nn.3328

Price, R. B., Kuckertz, J. M., Siegle, G. J., Ladouceur, C. D., Silk, J. S., Ryan, N. D., … Amir, N. (2015). Empirical recommendations for improving the stability of the dot-probe task in clinical research. *Psychological Assessment, 27*(2), 365-376. doi:10.1037/pas0000036

Price, R. B., Siegle, G. J., Silk, J. S., Ladouceur, C. D., McFarland, A., Dahl, R. E., & Ryan, N. D. (2014). Looking under the hood of the dot-probe task: An fmri study in anxious youth. *Depression and Anxiety, 31*(3), 178-187. doi:10.1002/da.22255

Roy, A. K., Vasa, R. A., Bruck, M., Mogg, K., Bradley, B. P., Sweeney, M., Bergman, R.L., McClure-Tone, E.B., & Pine, D. S. (2008). Attention bias toward threat in pediatric anxiety disorders. *Journal of the American Academy of Child & Adolescent Psychiatry, 47*(10), 1189-1196. doi:10.1097/chi.0b013e3181825ace

Schmidt, N. B., Richey, J. A., Buckner, J. D., & Timpano, K. R. (2009). Attention training for generalized social anxiety disorder. *Journal of Abnormal Psychology, 118*(1), 5-14. doi:10.1037/a0013643

Schmukle, S. C. (2005). Unreliability of the dot probe task. *Eur. J. Pers, 19*(7), 595-605. doi:10.1002/per.554

See, J., MacLeod, C., & Bridle, R. (2009). The reduction of anxiety vulnerability through the modification of attentional bias: A real-world study using a home-based cognitive bias modification procedure. *Journal of Abnormal Psychology, 118*(1), 65-75. doi:10.1037/a0014377

Sevar, K., Vythilingum, B., & Castle, D. (2015). Anxiety and Related Disorders in Women. *Anxiety Disorders and Gender*, 137-154. doi:10.1007/978-3-319-13060-6_7

Shalev, L., & Algom, D. (2000). Stroop and Garner effects in and out of Posner's beam: Reconciling two conceptions of selective attention. *Journal of Experimental Psychology: Human Perception and Performance*, *26*(3), 997-1017. doi:10.1037/0096-1523.26.3.997

Spielberger, C. D., Gorsuch, R. L., & Lushene, R. E. (1970). Manual for the State-Trait Anxiety Inventory (Self-Evaluation Questionnaire). Palo Alto, CA: Consulating Psychology Press.

Taylor, C. T., Aupperle, R. L., Flagan, T., Simmons, A. N., Amir, N., Stein, M. B., & Paulus, M. P. (2013). Neural correlates of a computerized attention modification program in anxious subjects. *Soc Cogn Affect Neurosci*, *9*(9), 1379-1387. doi:10.1093/scan/nst128

Torrence, R. D., Wylie, E., & Carlson, J. M. (2017). The Time-Course for the Capture and Hold of Visuospatial Attention by Fearful and Happy Faces. *Journal of Nonverbal Behavior*, *41*(2), 139-153. doi:10.1007/s10919-016-0247-7

Trick, L. M., & Enns, J. T. (1998). Lifespan changes in attention: The visual search task. *Cognitive Development*, *13*(3), 369-386. doi:10.1016/s0885-2014(98)90016-8

Westen, D., & Morrison, K. (2001). A multidimensional meta-analysis of treatments for depression, panic, and generalized anxiety disorder: An empirical examination of the status of empirically supported therapies. *Journal of Consulting and Clinical Psychology*, *69*(6), 875-899. doi:10.1037//0022-006x.69.6.875

Wiers, C. E., & Wiers, R. W. (2016). Imaging the neural effects of cognitive bias modification training. *NeuroImage*. doi:10.1016/j.neuroimage.2016.07.041

Williams, J. M., Mathews, A., & MacLeod, C. (1996). The emotional Stroop task and psychopathology. *Psychological Bulletin*, *120*(1), 3-24. doi:10.1037/0033-2909.120.1.3

Williams, J. M. G., Watts, F. N., MacLeod, C., & Mathews, A. (1988). Cognitive psychology and emotional disorders. John Wiley & Sons.

APPENDIX A

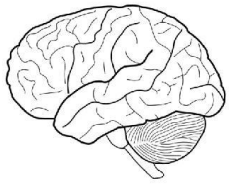
Flyer for Participant Recruitment

NMU IRB Approved: HS16-723

Are you looking for a way to earn a little extra cash this semester?

CABIN Lab is looking for research participants who will be compensated **$24** for participating in the following:

- 2 Testing Sessions (~60 minutes each)
- 4 Training Sessions (~20 minutes each)
- Collectively ~3 hours of participation spread over 2 weeks



Training and testing sessions will consist of a simple task where the participant is to indicate the location of a dot on a computer screen. Brain activity will be recorded using near-infrared spectroscopy (NIRS) during testing sessions.

CABIN

If interested in participating, please contact Jake Aday at jaday@nmu.edu to schedule your first session. Supervised by Dr. Josh Carlson, Department of Psychology.

APPENDIX B

Instruction Scripts

Protocol for "Evaluating the Use of Self-Relevant Stimuli in Attention Bias Modification (ABM) Training as a Treatment for Anxiety" **Testing Session 1**

Greet & welcome participant. *Ask them to turn off or silence their cellphone.*

Make sure the NIRS/EEG lab is dark (lights off & blinds drawn). Turn on lights in participant room.

1) Have the participant fill out the Informed Consent sheet and ask if they have any questions.
2) Collect basic demographic information from participant and enter it into the Excel sheet "Subject Info Sheet". This is in the Dropbox folder "Jake's Thesis", then click "Experiment Materials".
3) Schedule what days they can come in for training for the next two weeks using the calendar "ABM Study Calendar" in CABIN's Gmail calendar. Save them as "Participant (x) Training or Testing Session (x)". All appointments should be made within 2 weeks (no more than 3 weeks) and participants can't do more than one session in a single day. Note that the final training session will be immediately followed by the final testing session so they will be here for about 60-75 minutes on that day. Make sure to check

that the NIRS room will be available on their final testing day (calendar: “NMU NIRS Testing Room Schedule”) and add their testing session time on that calendar as well. Training Sessions will take up a half hour block and Testing Sessions will take up a hour and a half block (just to be safe). Therefore, you can schedule up to 4 Training Sessions in one research assistant’s 2-hour block or 1 Testing Session and 1 Training Session in the 2-hour block.

4) Copy their scheduled times onto the reminder sheet for participants to take home.
5) If they didn’t bring in a list, give the participants the paper to write down the 10 things that cause them the most anxiety. *Be sure to tell the participant to limit their answers to one word responses between 3-11 letters. If they have trouble coming up with enough words, have them think of things they find threatening or worrying.* If they are unable to generate a list in 10 minutes, you may give them the Negative Word List to help them identify words they find threatening to them.
6) For each anxiety word, have the participants choose a corresponding word from the Neutral Word List that is emotionally neutral to them and the same number of letters.
7) Seat them at the testing computer and on the desktop, open up the folder “Jake’s Thesis NIRS Dot-Probe” and open the file “DOT-PROBE NIRS”.
8) Enter the requested information. **“1” should be entered for session if it’s the pre-training session.**
9) Then attach the NIRS device to the participants’ forehead (see “Protocol for NIRS”).
    a. Don’t put the headband or bandage on until you’ve collected the 3D Digitizer points (since you won’t be able to see the sources or detectors with them on).

10) Then attach use the 3D digitizer to mark coordinates of interest (see “Protocol for 3D Digitizer”).

11) Make sure the participant is seated 59 cm from the screen and give them the following instructions:

Each trial of the experiment will start with a small ‘+’ (plus sign) in the center of the screen. At all times keep your eyes fixated on the plus sign. After a period of fixation, two stimuli will be briefly presented: one on the left side and one on the right side of the screen. After these stimuli disappear, a small dot will appear on the left or right side of the screen. Your task is to locate this dot. To do this, use your right index finger on the 1st (left most) button on the response box to indicate target dots on the left. Use your right middle finger on the 2nd button on the response box to indicate target dots on the right. IT IS IMPORTANT THAT YOU RESPOND AS QUICKLY AS POSSIBLE. AS SOON AS YOU LOCATE THE DOT MAKE A RESPONSE. In between trials, there will be a 7 second gap; please try to avoid distractions and stay focused on the task during this time. DO YOU HAVE ANY QUESTIONS?

12) Tell them to knock on the window when the experiment has concluded.

13) Following the experiment, unhook them from the NIRS device and wheel it to the corner before opening the questionnaire (“STAI”) for them to complete. There will be two questionnaires within this file: the first asking how the *currently* feel and the second how they *generally* feel.

14) Following the session, walk the participant down to the CABIN lab to begin their first training session.

Protocol for “Evaluating the Use of Self-Relevant Stimuli in Attention Bias Modification (ABM) Training as a Treatment for Anxiety” **NIRS Protocol**

1. Wheel the NIRS device over so that it is about 2 feet or so behind the participant.
2. Plug in the machine and begin turning it on by flipping the green switch on the side of the cart. Then turn on the white box and then finally turn on the computer on the NIRS cart.
3. Next, plug in the USB cord coming from the NIRS cart into the *far left USB port* on the *front* of the testing computer.
4. Open the red program “cw6” on the desktop of the NIRS computer.
5. It will prompt you to open up a directory. Select Desktop, then select the CABIN folder, then select Strangeglove2 and open it.
6. If a NIRS probe from another study is currently hooked up, unplug the optodes and insert them into our probe. Match the optodes with the array shown in the cw6 program.
7. Use a tape measure to measure from the nasion (bridge of nose) to the inion (bump on back of head). Take 10% of that length and make a mark that is that distance from the nasion. (So if it’s 100cm from the nasion to the inion, then you’d make a mark 10cm above the nasion).
8. Also measure the circumference of their head (start the tape measure at the nasion and wrap it around the head so that it goes over the inion) and record the data in centimeters in the file “Subject Info Sheet”.
9. Next attach the NIRS probe to the participant’s head using the Velcro straps. Make sure the central detector is situated where you placed the mark on their forehead.
10. Cover the probe with a headband and then wrap the Ace bandage around the headband to keep light from leaving or getting into the probe.

11. Then attach use the 3D digitizer to mark coordinates of interest (see “Protocol for 3D Digitizer”).
12. If you haven’t already, open up the dot-probe task on the participant computer and enter their information.
13. See “Testing Protocol” for testing instructions to read to the participant.
14. **Check the auxiliary ports in the bottom-right portion of the CW6 program, Turn on all sources, and press START before leaving.**
15. The lights in the testing and control room should be turned off.
16. After the task is over, give the participant the STAI and then move on to their first training session if it’s their first day. If it’s their last day, they can be debriefed on the nature of the study and told to stop by Jake’s office (1133 NSF) for their check.
17. After the session is over, make sure you move the data over from the “Data - Shortcut” folder on the desktop (the file will be labelled as that day’s date) to “Jake’s Thesis” which will also be on the desktop and relabel it as their participant number (ex. 01)
18. Shut down the computers and be sure to wheel the NIRS device back to the corner and unplug it from the wall and testing computer.

Protocol for “Evaluating the Use of Self-Relevant Stimuli in Attention Bias Modification (ABM) Training as a Treatment for Anxiety” **3D Digitizer Protocol**

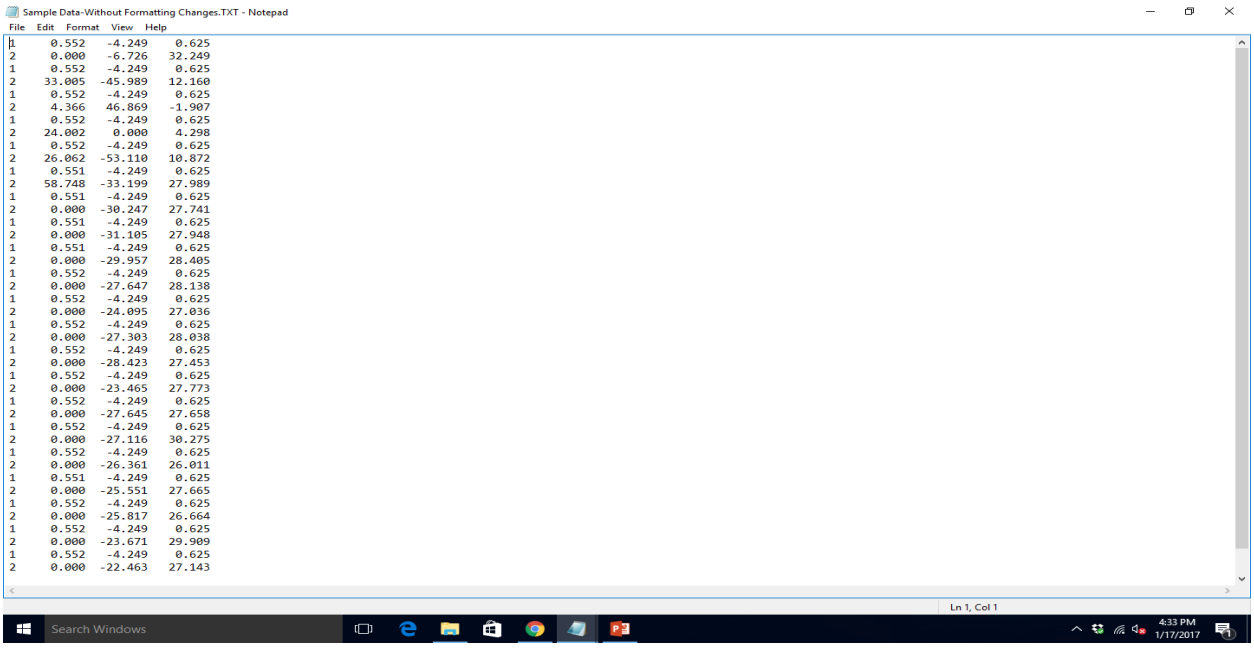
1) After securing the NIRS probe to their head, place the block for the 3D digitizer (it’s plugged into the “Source” channel) on the NIRS cart and secure the sensor plugged into “Sensor 1” somewhere on top of their head in the NIRS wires (nowhere in particular)
2) Next, open up the program “PiMgr” on the testing computer.
3) Immediately press the red “record” button in the top right corner of the window.
4) Next you’ll begin plotting points using the stylus plugged into “Sensor 2”. You’ll want to be careful when plotting points since the button is sensitive and will begin recording multiple points if you hold it down for too long. Watch the computer screen as well to make sure it picked up your point.
5) *Points **can’t** be undone once made so be careful or you’ll have to exit out and start over. Also, it is **critical** that you make the points in the order listed*.
6) (1) First make a point at the nasion (nz; bridge of nose), (2) then the right temple (ar), (3) then the left temple (al), (4) then a point halfway between the nasion and inion (cz; you measure between the nasion and inion when putting the NIRS probe on so try to remember that number so you don’t have to measure it again with the probe on their head), (5) then make a mark on the inion (iz).
7) Next, make a point at each of the sources (top row of NIRS probe) starting at “A”.
8) Then, make a point at each of the detectors (bottom row of NIRS probe) starting with “1”.

9) Go back to the “PiMgr” program, go to “File”, “Export Motion Recording” and save as a txt file in the folder “Participants’ 3D Digitizer Coordinates” found at Desktop<Jake’s Thesis NIRS Dot-Probe<Participants’ 3D Digitizer Coordinates. Save as their subject number in the pre or post folder depending on the session.

10) Move the digitizer equipment back to the printer stand before starting experiment.

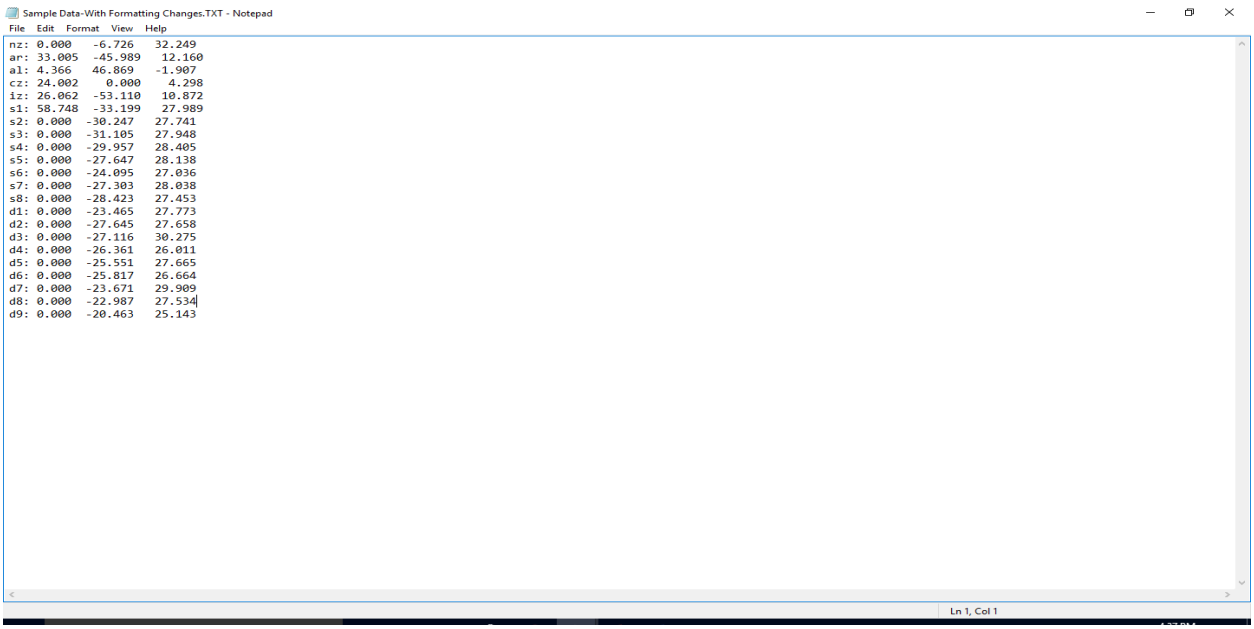
11) Lastly, after the participant’s session is completely over, you will need to go back and reformat the text file that was generated for the 3D Digitizer.

    a. First, open up the unformatted text document that you saved earlier, it should look something like this:



    b. Then, delete each row that starts with a “1”

    c. Then, reformat each of the “2” columns so that they look like this:



The first 5 rows will be the head landmarks you took (nz, ar, al, cz, iz). The next 8 rows will be the sources (s1-s8) and the final 9 rows will be the detectors (d1-d9). Leave just one space between the colon (:) and the coordinates. This is why it is critical you make the points in the exact order listed.

Protocol for “Evaluating the Use of Self-Relevant Stimuli in Attention Bias Modification (ABM) Training as a Treatment for Anxiety” **Training Sessions**

Greet & welcome the participant. *Ask them to turn off or silence their cellphone*

1) Guide the participant to the training room and make sure their computer monitor is OFF until you have the experiment ready to go.
2) If it is their first training session, you will need to incorporate their list of 10 things that cause them the most anxiety into E-Prime.
    a. Go to the Dropbox Folder “Jake’s Thesis”, then “Experiment Materials”.
    b. Choose either “Thesis Experiment-BLANK - Control.es2” or “Thesis Experiment-BLANK – Treatment.es2” depending on which group they are assigned to.
    c. Regardless of condition, double-click “Wordlist” in the Structure Window
    d. Enter the 10 things that they listed as causing them anxiety in the column “FearWord”
    e. Next, enter in the neutral words of equal length in the “NeutWord” column.
    f. Once you have finished entering all of their words, go to “Save As” and save the file in the folder “Participant E-Prime Files” as their subject number (For example, if I was the first subject my file would be called “01”.)
    g. Click the “run” icon on the top of the screen to begin the experiment.
3) If it’s not their first training session, then go to the Dropbox folder “Jake’s Thesis”, “Experiment Materials” , and finally “Participant E-Prime Files”

4) Select the corresponding participant number and begin the program. You'll be opening the icon with a person running on it.
5) Once the experiment is programmed, make sure the participant is seated 59cm from the screen (chair is at the tape) and read the following instructions:

   Each trial of the experiment will start with a small "+" (plus sign) in the center of the screen. At all times keep your eyes fixated on the plus sign. Two words will then appear, one on the top and bottom of the screen. One of the words will be a word you previously identified as causing you anxiety and on the other side will be a word of equal length. After these stimuli disappear, a small dot will appear on either the top or bottom side of the screen. Your task is to locate this dot. To do this, use your right index finger on the 1st (leftmost) button on the response box to indicate target dots on the top. Use your right middle finger on the 2nd button on the response box to indicate target dots on the bottom. IT IS IMPORTANT THAT YOU RESPOND AS QUICKLY AS POSSIBLE. AS SOON AS YOU LOCATE THE DOT MAKE A RESPONSE. The experiment will be divided into several blocks. Between blocks you can take a small break if you like. When you are ready to begin the next block press the "1" button. DO YOU HAVE ANY QUESTIONS?

6) Following the training session, ask the participant if they have any further questions. If they do not, then thank them for their participation and confirm their next scheduled session.
7) If it's their final training session, proceed to the NIRS room to complete their final testing session.

Protocol for "Evaluating the Use of Self-Relevant Stimuli in Attention Bias Modification (ABM) Training as a Treatment for Anxiety" **Testing Session 2**

1) Immediately following their final training session, walk the participant down to the NIRS/EEG room.
2) Seat them at the testing computer and on the desktop, open up the folder "Jake's Thesis NIRS Dot-Probe" and open the file "DOT-PROBE NIRS".
3) Enter the requested information. **"2" should be entered for session if it's the post-training session.**
4) Next, attach the NIRS device to the participants' forehead (see "Protocol for NIRS").
5) Then attach use the 3D digitizer to mark coordinates of interest (see "Protocol for 3D Digitizer").
6) Make sure the participant is seated 59 cm from the screen and give them the following instructions:

   Each trial of the experiment will start with a small '+' (plus sign) in the center of the screen. At all times keep your eyes fixated on the plus sign. After a period of fixation, two stimuli will be briefly presented: one on the left side and one on the right side of the screen. After these stimuli disappear, a small dot will appear on the left or right side of the screen. Your task is to locate this dot. To do this, use your right index finger on the 1st (left most) button on the response box to indicate target dots on the left. Use your right middle finger on the 2nd button on the response box to indicate target dots on the right. IT IS IMPORTANT THAT YOU RESPOND AS QUICKLY AS POSSIBLE. AS SOON AS YOU

LOCATE THE DOT MAKE A RESPONSE. In between trials, there will be a 7 second gap; please try to avoid distractions and stay focused on the task during this time. DO YOU HAVE ANY QUESTIONS?

7) Following the experiment, open up the STAI questionnaire and enter the participant's information.
8) Following the session, debrief the participant on the nature of the experiment and give them the subject debriefing sheet. Let them know to come to Jake's office (1133 NSF, Office Hours MW 11-1) for their check.

APPENDIX C

List of Anxiety-related and Neutral Words

Anxiety-related Words

abandonment	bathrooms	chewing	crowds	death
abandonment	bathrooms	children	crowds	death
abuse	better	choking	crowds	debt
abuse	bills	cicadias	crowds	debt
academics	boys	classes	crowds	debt
accident	bridges	class-project	crying	debt
accident	broken	cleaning	dark	debt
accident	broken	clowns	darkness	debt
accidents	burning	commitment	darkness	decisions
acute	busy	commitment	dead	decisions
addiction	bylee	communicate	deadline	dementia
adulthood	calculus	compete	deadline	dementia
advanced	calling	competition	deadline	dentist
afraid	cancer	complex	deadlines	dentist
alleyways	cancer	conflict	deadlines	dependent
alone	cancer	conformity	death	dependent
alone	cancer	confusion	death	depression
alone	cancer	consoled	death	destroy
alone	cancer	consuming	death	direction
alone	career	control	death	disappoint
aloud	career	control	death	disappoint
anger	career	control	death	disappoint
angry	career	coughing	death	disappoint
annoying	casting	crashes	death	disease
annoying	cellar	crashing	death	disease
appearance	chainsaw	criminals	death	disease
arrested	change	criticism	death	disorder
assignment	change	crowds	death	disrespect
audition	change	crowds	death	dissension

divorce
divorce
divorce
doubt
doug
drama
driving
driving
driving
driving
drown
dystopian
election
elevator
equality
evaluation
exam
exam
exam
exam
exam
exam
exam
exam
exam
exam
exams
exams
exams
exams
exams
exams
exams
exams
exercise
expectation
expectation
expectation
expectation
expensive
explain
explanation
extension
fail
fail
fail
failed
failing
failing
failing
failing
failing
failing
failing
failure
failure
failure
failure
failure
failure
failure
failure
failure
failure
failure
failure
failure
failure
failure
failure
failure
failure
failure
family
family
family
family
family
family
fascist
father
fear
feelings
feelings
fidgety
fight
fighting
fighting
final
finances
finances
finances
fire
fire
fire
flawed
football
foreboding
forever
forgot
friends
friends
frozen
funerals
futile
future
future
future
future
future
future
future
future
future
future
future
future
future
future
future
germs
girls
girls
god
government
government
grade
grades
grades
grades
grades
grades
grades
grades
grades
grades
grades
graduation
graduation
grandfather
groups
guilt
hairdryer
hairpin
happiness
harassment
hate
hate
hatred
headlight
health
health
health
heartbreak
heat
heights
heights
hell
helpless
hide
homework
homework
homework
homework
homophobia
hopeless
horny
hospitals
hospitals
hurry
hurt
ice
ignorance
ignore
illness
illness
impromtu
inadequate
incomplete
inescapable
infatuation
injury
injury
injury
injury
injury
injury
injustice
insurance
insurance
internships
interview
interviews
jack
job
job
job
job
job
judgment
judgments
keys
lacking
last
late
late
late
late
late
late
lateness
leadership
learning
leaving
liar
limit
loans
loans
loans
loneliness

loneliness
loneliness
losing
losing
loss
loss
loss
loss
loss
lost
lost
lost
lost
love
love
maggots
major
marriage
marriage
masks
math
math
math
mess
mice
minutes
miscarriage
mocking
moist
mom
money
money
money
money
money
money
money
money
money
money
money
money
money
money
money
money
money
money
money
mortgage
moving
murder
mysteries
needles
needles
never
new
nigger
nothing
nuns
obesity
ocean
over
overdue
overwhelmed
pain
pain
pain
panic
paradox
parents
perfection
performing
permanent
plan
plan
planning
plans
pneumonia
poison
poison
police
police
police
politics
politics
politics
practicals
present
present
presentation
president
pressures
privacy
promise
public
pus
quiz
quiz
racing
racism
raccoon
rape
rape
rape
read
re-do
regret
rejection
rejection
relentless
religion
represent
required
reserved
residents
roach
robbery
roommates
rushed
rushing
school
school
school
school
school
school
school
school
scuba-diving
sea
semi
separated
serious
sexism
shoo
shooting
shootings
shopping
shouting
sickness
sickness
sickness
silence
silence
sirens
skyscraper
slime
snake
snakes
sniffling
social
socializing
social-life
sociology
something
sorry
speaking
speech
speeches
spider
spider
spiders
spiders
sports
sprints
stalking
starving
stereotypes
stock
stop
strangers
stress
stress
stroke
struggle
struggle
studio
studying
studying
studying
success
success
suffocate
surgeries
surgery
surgery
surprises
talk
talking
tardiness
taunting
terrorism
test
test
test
test
test
test
tests
tests
threaten
thrillers
time
time
time
time
time
tooth
tornadoes
transition
transition
trauma
trouble
trump
trump
trump
trust
ugly
uncertain

uncertainty	unorganized	watching	work	wrong
uncontrol	unprepared	water	work	yelling
under	unprepared	weather	work	yelling
unknown	upset	weight	work	yelling
unknown	vulnerable	weight	work	yelling
unknown	war	weight	work	yelling
unknown	war	what-ifs	worthless	yelling
unknown	washing	wind	wrong	yelling
unorganized	waste	work	wrong	zombies

Neutral Words

absurd	avenue	bench	building	chin
activate	avenue	bench	building	chin
activate	avenue	bench	bus	circle
alley	avenue	bench	butter	circle
aloof	avenue	black	butter	circle
ankle	avenue	black	cabinet	circle
ankle	avenue	bland	cabinet	circle
ankle	avenue	bland	cabinet	circle
ankle	banner	bland	cabinet	circle
ankle	banner	blase	cabinet	circle
ankle	banner	board	cabinet	circle
ankle	barrel	board	cane	circle
appliance	basket	board	cane	cliff
appliance	basket	body	cannon	cliff
appliance	basket	book	cannon	clock
appliance	basket	book	cat	clutter
appliance	Basket	book	cellar	coast
appliance	bathroom	book	chair	coast
appliance	bathroom	book	chair	coast
appliance	bathroom	book	chair	cold
appliance	bathroom	book	chair	column
appliance	bathroom	book	chair	column
appliance	beast	bowl	chair	column
appliance	bench	bowl	chair	computer
appliances	bench	bowl	chin	concentrate
arm	bench	boxer	chin	concentrate

concentrate	dirt	frog	hay	item
concentrate	dirt	frog	headlight	item
concentrate	doctor	frog	headlight	jelly
consoled	doctor	fun	headlight	jelly
consoled	doctor	fur	headlight	journal
consoled	doctor	gender	heights	journal
consoled	doghouse	glacier	hide	journal
contents	door	glacier	highway	kerosene
contents	door	glass	highway	ketchup
contents	drowning	glass	highway	ketchup
context	elbow	golfer	highway	ketchup
context	elbow	golfer	history	ketchup
context	elbow	golfer	history	ketchup
cord	elbow	habit	horse	ketchup
cord	elbow	habit	hospital	ketchup
cord	elbow	hairdryer	hospital	kettel
cord	elevator	hairdryer	hospital	kettel
cord	elevator	hairdryer	hotel	kettle
cork	elevator	hairdryer	humble	kick
corner	elevator	hairdryer	humble	lamp
corner	elevator	hairdryer	humble	lamp
corridor	embattled	hairdryer	hydrant	lamp
corridor	embattled	hairdryer	hydrant	lamp
corridor	embattled	hairdryer	hydrant	lamp
corridor	engine	hairdryer	hydrant	lantern
corridor	engine	hairdryer	icebox	lantern
curtains	engine	hairdryer	indifferent	lantern
curtains	errand	hairdryer	indifferent	lantern
curtains	exam	hairpin	indifferent	lantern
curtains	fabric	hairpin	indifferent	lantern
custom	fabric	hairpin	indifferent	lantern
custom	fabric	hairpin	indifferent	lantern
custom	fabric	hairpin	indifferent	lantern
dark	Fall	hairpin	industry	lawn
dark	Fall	hairpin	inhabitant	lawn
defiant	Fall	hairpin	inhabitant	lawn
dentist	Farm	hammer	inhabitant	lawn
dentist	Farm	hand	inhabitant	lightbulb
detail	finger	hand	ink	lightbulb
detail	finger	hard	ink	lightbulb
detail	finger	hard	insect	lightbulb
detail	Foot	hat	invest	lightbulb
dirt	fork	hawk	iron	lightbulb
dirt	frog	hawk	item	lightbulb

lightbulb
lightbulb
lightbulb
lightbulb
lightbulb
lightbulb
lighthouse
lighthouse
lighthouse
lighthouse
lighthouse
lighthouse
lighthouse
lighthouse
limber
lion
lion
lion
locker
locker
locker
manner
manner
manner
mantel
mantel
mantel
mantel
market
market
material
material
material
material
medicine
medicine
medicine
metal
metal
method
milk
milk
milk
milk
mischief
mischief
modest
moment
moment
moment
month
month
muddy
museum
museum
museum
museum
mushroom
mushroom
mushroom
mushroom
mushroom
name
name
news
news
news
nonchalant
nonchalant
nonchalant
nonchalant
nonchalant
nonchalant
nonchalant
nonchalant
nonsense
nursery
office
office
owl
owl
paint
paint
paint
pamphlet
pamphlet
pamphlet
pamphlet
paper
paper
paper
paper
part
passage
passage
patient
patient
pencil
pencil
pencil
pencil
pencil
pencil
pencil
pig
plain
plain
plain
plain
plain
planning
plant
plant
plant
poetry
poster
prairie
prairie
prairie
prairie
present
privacy
privacy
quart
quart
radiator
repentant
repentant
repentant
reptile
reptile
reptile
reptile
reptile
reptile
reverent
reverent
rock
rock
router
runner
salad
salad
salad
scissors
scissors
scissors
scissors
sentiment
sentiment
sentiment
sentiment
sentiment
sentiment
sentiment
serious
serious
shelter
ship
shy
skeptical
skyscraper
skyscraper
skyscraper
skyscraper
skyscraper
skyscraper
skyscraper
skyscraper
skyscraper
skyscraper
skyscraper
sphere
sphere
spray
square
square
stagnant
stiff
stomach
stool
storm
storm
stove
street
suffocate
swamp
sweats
table
table
tag
tamper
tank
tardiness
taxi
taxi
taxi
taxi
teacher
teacher
tease
telephone
thermometer
thermometer
thermometer
thermometer

thermometer	umbrella	village	whistle
thermometer	umbrella	village	whistle
thermometer	umbrella	village	whistle
thermometer	unit	village	whistle
thermometer	unit	village	whistle
time	utensil	village	windmill
time	utensil	village	windmill
trumpet	utensil	violin	window
trumpet	utensil	volcano	wine
trumpet	vest	voting	wire
trumpet	vest	wagon	woods
trumpet	vest	wagon	writer
trumpet	vest	watch	yellow
trunk	vest	watch	yellow
umbrella	village	whistle	yellow

APPENDIX D

Additional Analyses with Only High-Anxious Individuals

Given that our overall results are somewhat limited by the use of non-clinical sample, we ran further analyses with just participants who were the most anxious prior to training. To do this, we looked at just the 8 participants in each group who scored highest on the STAI-T during the pre-training testing session (i.e. those who scored approximately in the 75th percentile or higher in our overall sample). A mixed methods ANOVA on reaction time yielded no main effects for group, $F(1, 14) = 0.05$, $p > 0.05$, $eta^2 = 0.004$, or session $F(1, 14) = 0.51$, $p > 0.05$, $eta^2 = 0.035$. The main effect of trial type was significant, $F(1, 14) = 4.65$, $p = 0.02$, $eta^2 = 0.249$, such that congruent trials ($M = 354.20$, *S.E.* = 15.17) were faster than incongruent ($M = 364.00$, *S.E.* = 13.99) and neutral trials ($M = 360.85$, *S.E.* = 15.88), which did not differ from one another. There were no interaction effects for session x group $F(1, 14) = 0.48$, $p > 0.05$, $eta^2 = 0.033$, group x trial type $F(1, 14) = 0.15$, $p > 0.05$, $eta^2 = 0.011$, or group x session x trial type $F(1, 14) = 1.37$, $p > 0.05$, $eta^2 = 0.089$. A mixed methods ANOVA was also run on their STAI-S scores, which yielded no main effects for group $F(1, 14) = 2.16$, $p > 0.05$, $eta^2 = 0.134$, or session $F(1, 14) = 0.11$, $p > 0.05$, $eta^2 = 0.008$. The group x session interaction was also non-significant $F(1, 14) = 2.29$, $p > 0.05$, $eta^2 = 0.140$. Lastly, a mixed methods ANOVA was run on their STAI-T scores, which yielded a main effect for group, $F(1, 14) = 6.72$, $p < 0.05$, $eta^2 = 0.324$, such that the treatment group ($M = 63.94$, *S.E.* = 2.27) scored higher than the control group ($M = 55.63$,

S.E. = 2.27) in this cohort of participants. The main effect of session was not significant $F(1, 14) = 0.22$, $p > 0.05$, $eta^2 = 0.015$, nor was the group x session interaction $F(1, 14) = 0.53$, $p > 0.05$, $eta^2 = 0.037$. These results indicate that the training did not affect those high in anxiety any differently compared to our non-clinical sample. These participants responded faster on congruent compared to incongruent and neutral trials (i.e. demonstrating an attentional bias), which is in-line with previous research showing that individuals high in anxiety demonstrate an attentional bias towards threat. However, our non-clinical sample demonstrated a comparable attentional bias overall.